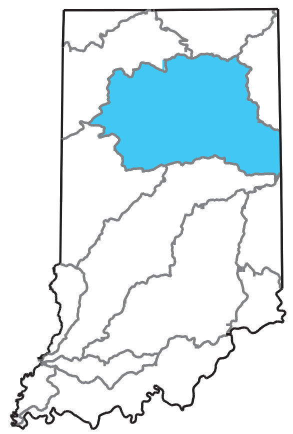


UPPER WABASH RIVER BASIN

By Theodore K. Greeman

General Description

For management purposes, the Indiana Department of Natural Resources has divided the Wabash River basin into three subbasins: an upper basin, a middle basin, and a lower basin. The Upper Wabash River basin extends from the Indiana-Ohio State line downstream to include Wildcat Creek (fig. 36) near Lafayette, Tippecanoe County (fig. 1). This area is approximately 110 mi east-west by 70 mi north-south.

The Upper Wabash River basin is 6,918 mi^2 and includes all or most of Blackford, Carroll, Cass, Clinton, Fulton, Grant, Howard, Huntington, Jay, Miami, Pulaski, Wabash, White, Whitley, and Wells Counties, and parts of 13 other counties. Principal cities in the basin include Bluffton, Columbia City, Frankfort, Hartford City, Huntington, Kokomo, Logansport, Marion, Monticello, North Manchester, Peru, Portland, Rochester, Wabash, and Warsaw (fig. 36).

Previous Studies

Numerous reports have been written on the hydrogeology of areas within the Upper Wabash River basin. One of the first was by Capps (1910), who described ground-water sources and artesian-well areas in the central part of this basin. Harrell (1935), in his comprehensive hydrologic report on Indiana, described the general features, geology, drainage, ground-water resources and sources of water for each county in Indiana. Although some information in Harrell's report is dated, the report is useful as a historical documentation of early water use.

In the 1950's and early 1960's, the Indiana Department of Conservation, Division of Water Resources (now called Department of Natural Resources, Division of Water) published a partial series of county ground-water-resource reports. Nine of these reports, discussed below, describe areas within the Upper Wabash River basin. Of the counties described in these reports, only Fulton County is wholly within the Upper Wabash River basin.

Stallman and Klaer (1950) described ground-water availability in Noble County. Lithologic logs of numerous wells are included, as well as a potentiometric-surface map. Rosenshein and Cosner (1956) and Rosenshein (1958) reported on the ground-water resources of Tippecanoe County. The 1956 report presents well-log data and water-level measurements, whereas the 1958 report describes the glacial and bedrock geology, bedrock topography, hydrologic cycle, ground-water quality and ground-water use. Rosenshein's 1958 report also includes a potentiometric-surface map and nine geologic-sections; it identifies five confined aquifers near Lafayette. Watkins and Ward (1962) reported on the ground-water resources of Adams County. Their report includes ground-water-quality information and lithologic logs of numerous wells.

Four more county reports were published in 1964. These reports, authored by Rosenshein and Hunn (1964a, 1964b, 1964c, 1964d), address the four adjoining counties of Marshall, Fulton, Starke, and Pulaski . All four reports describe the general geology, general sources of ground water, and general water-quality information. Tables include lithologic logs of numerous wells and data on ground-water quality. The last in this group of nine county reports describing parts of the Upper Wabash River basin is Hoggatt and others (1968). This report disscusses the quantity, distribution, and quality of the water resources in Delaware County.

Watkins and Rosenshein (1963) were the first to report the hydrologic properties of the bedrock in the Upper Wabash River basin. They described the transmissivity, storage and recharge rates for the Silurian bedrock near Bunker Hill, Miami County. Although the values are site specific, they were derived from aquifer tests and are representative of the Silurian bedrock.

In 1971, the Wabash River Coordinating Committee released an eight-volume "plan for the conservation, management, development and proper preservation of the water and related land resources of the Wabash River Basin" (appendix B, p. ii). These reports describe the same management basins as are described in this report. The section about ground water by Nyman and Pettijohn (1971) contains a summary of nondomestic well data for the Upper Wabash River basin, specific-capacity and well-yield data for unconsolidated aquifer sources, and estimates of potential yields to large-diameter wells from different aquifer types.

Two Hydrologic Investigations Atlases published by the U.S. Geological Survey present information on the Upper Wabash River basin. The first report (Tate and others, 1973) contains information on the water resources in the eastern half of the basin. Map data on ground-water quality, surface-water quality, hydrologic balance, surface-water flow duration, surface-water stage and discharge, unconsolidated-aquifer transmissivity, and the potentiometric surface are presented. The study area includes all of the Wabash River drainage basin upstream from Logansport, east to the Indiana-Ohio State line (fig. 36).

The second Hydrologic Investigations Atlas (Marie and Davis, 1974) pertains to the western half of the Upper Wabash River basin. This map report presents much of the same type of information presented in the earlier report by Tate and others, but at a different map scale. The report by Marie and Davis pertains to the Wabash River basin downstream from Logansport to Lafayette, slightly beyond the western basin boundary used for this report (fig. 36).

Bleuer and Moore (1972) were the first to describe and correlate glacial stratigraphy in the Allen County area. Bleuer and Moore (1978) subsequently described the glacial geology, ground-water availability, ground-water quality, and the potential for deep-well waste disposal in Allen County. These two reports represent a continued effort to identify and map the stratigraphic units within the unconsolidated drift.

A recent trend in ground-water investigations is toward model studies. Planert (1980), in his report on the hydrogeology of parts of Allen, Noble, and Whitley Counties within the Upper Wabash River basin, modeled several ground-water sources and simulated ground-water withdrawal to evaluate streamflow losses and ground-water-level declines. Gillies (1981) examined the ground-water resource potential near Logansport, Cass County. Maps of the geology, a buried-valley aquifer, and the potentiometric surface are presented. A computer model was used to simulate the effects of pumping on ground-water levels and streamflow at two locations. Smith and others (1985) reported on the Wildcat Creek and Deer Creek drainage basins in Howard County and parts of adjacent counties. This report describes streamflow, hydrologic characteristics of aquifers and confining beds, aquifer-stream interaction, and ground-water and surface-water quality. The report also presents model simulations that indicate the effects of pumping on ground-water levels and streamflow.

Bleuer (1989) reported on the buried Lafayette Bedrock Valley System (formerly the Teays-Mahomet Valley System) that converges on Lafayette, Indiana. Bleuer (1991) interpreted the sequence of valley-segment formation and the sedimentary facies and stratigraphy of the valley fill in the buried-valley system. Bleuer and others (1991) described the availability of ground-water resources from various segments of the Lafayette Bedrock Valley System within the Upper Wabash River basin. They also described the geology of several aquifers and confining beds.

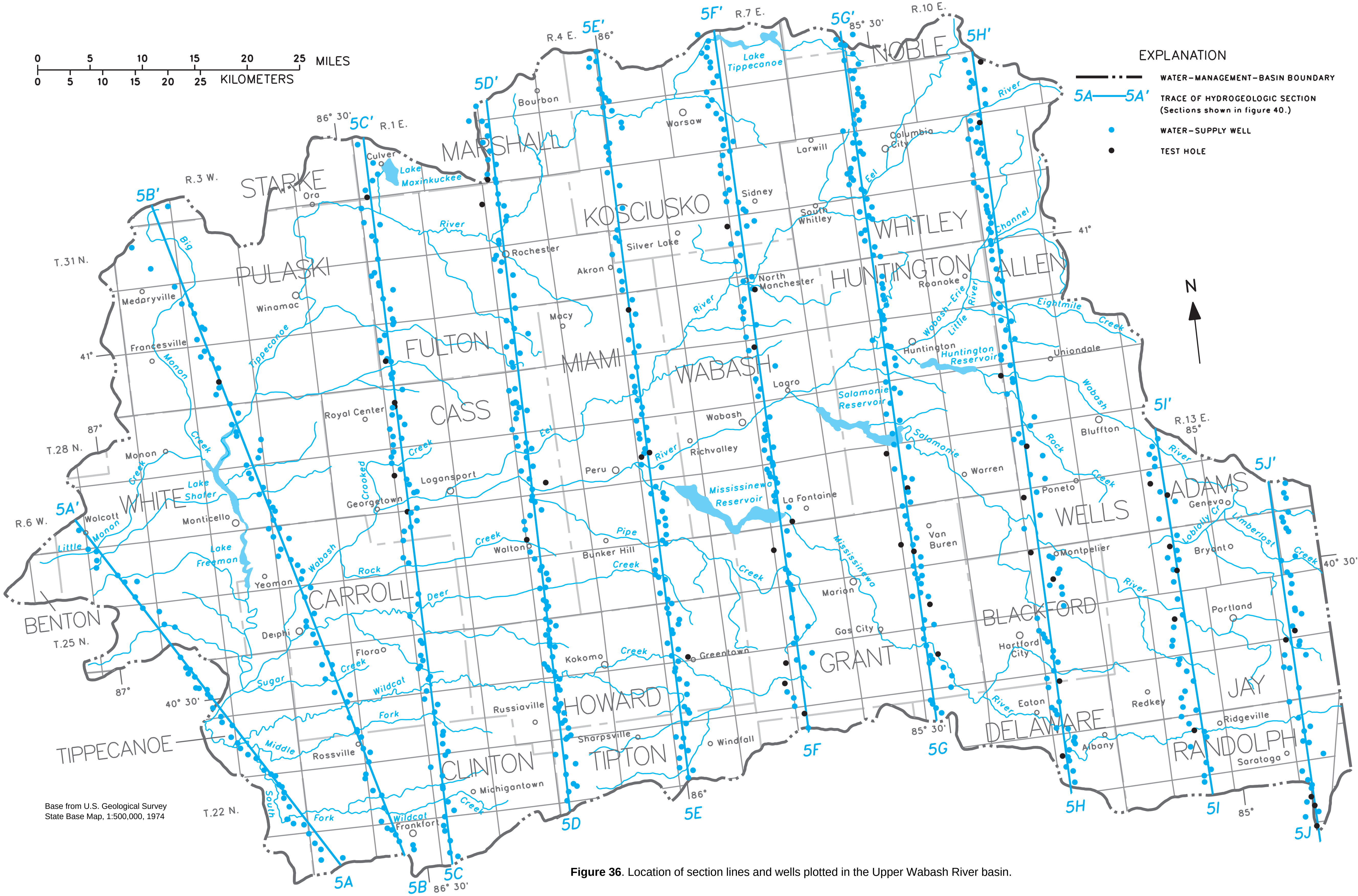


Figure 36. Location of section lines and wells plotted in the Upper Wabash River basin.

Physiography

The Upper Wabash River basin lies within two distinct physiographic areas (Schneider, 1966, p. 41): the Northern Moraine and Lake Region, located north of the Eel River, and the Tipton Till Plain, located predominately south of the Eel River. Except for occasional bedrock exposures and recent stream deposits, most physiographic features in the Upper Wabash River basin were formed by glaciers during Pleistocene time.

The Northern Moraine and Lake Region in the Upper Wabash River basin is characterized by moraines, outwash, and lake (lacustrine) plains. Depositional environments allow this northern area to be subdivided into two units: the Steuben Morainal Lake Area on the east and the Kankakee Outwash and Lacustrine Plain on the west (fig. 37).

The Steuben Morainal Lake Area is characterized by interlobate moraine topography. "Interlobate moraine" is a term coined by T.C. Chamberlin (1883) to describe the assemblage of moraines between two lobes of glacial ice. The moraine topography of the Steuben Morainal Lake Area is characterized by hummocky terrain and numerous kettle lakes that lack surficial drainage.

Glacial stratigraphy is very complex within the interlobate morainal deposits because slumping and ice thrusting obscured much of the original structure. Slumping occurred when entrapped ice melted and created surface depressions. Some depressions are filled with water, whereas others are drained. Hills composed of large blocks of reworked till, as well as ice-contact stratified sand and gravel (kames), are common. Local relief commonly ranges from 100 to 150 ft (Schneider, 1966, p. 52). Meltwater channels, outwash plains, and sand dunes also are common.

The Kankakee Outwash and Lacustrine Plain is characteristically flat and poorly drained. Sand, deposited as outwash by glacial meltwaters, lies at or near the surface throughout much of the area. Most deposits of sand are in valley trains, outwash plains, and lake-sand deposits associated with the Tippecanoe River. Prevailing westerly winds have rearranged the sand into dunes in White and Pulaski Counties.

South of the Eel River is the Tipton Till Plain. The till plain surface is nearly flat to gently undulating, poorly drained, and featureless. Surface relief is generally less than 10 ft per 1,000 ft. The till plain is underlain by ground moraine and ablation tills. Resurgent periods during the retreat of the last glacial ice produced large concentric recessional moraine ridges (fig. 37). Relief across the moraines is low, generally less than 50 ft, although relief is slightly greater in several areas. The recessional moraines are 1 to 6 mi wide. Stratigraphy in the till plain area tends to be more horizontally continuous and less complex than in morainal deposits, except where thin till covers morainal deposits.

The Wabash Moraine (fig. 37), which forms the northeastern boundary of the Upper Wabash River basin, also forms the major divide between drainage to the St. Lawrence River and the Mississippi River. Lake Maumee, the high stage glacial-ancestor of Lake Erie, once overflowed the Wabash Moraine into the Wabash River basin. Shifting of the divide came about when the glacial ice retreated from the Lake Erie Basin, initiating drainage to the St. Lawrence River. Lake Maumee stopped draining across the Wabash Moraine about 12,000 years ago (Fullerton, 1980, pl. 1).

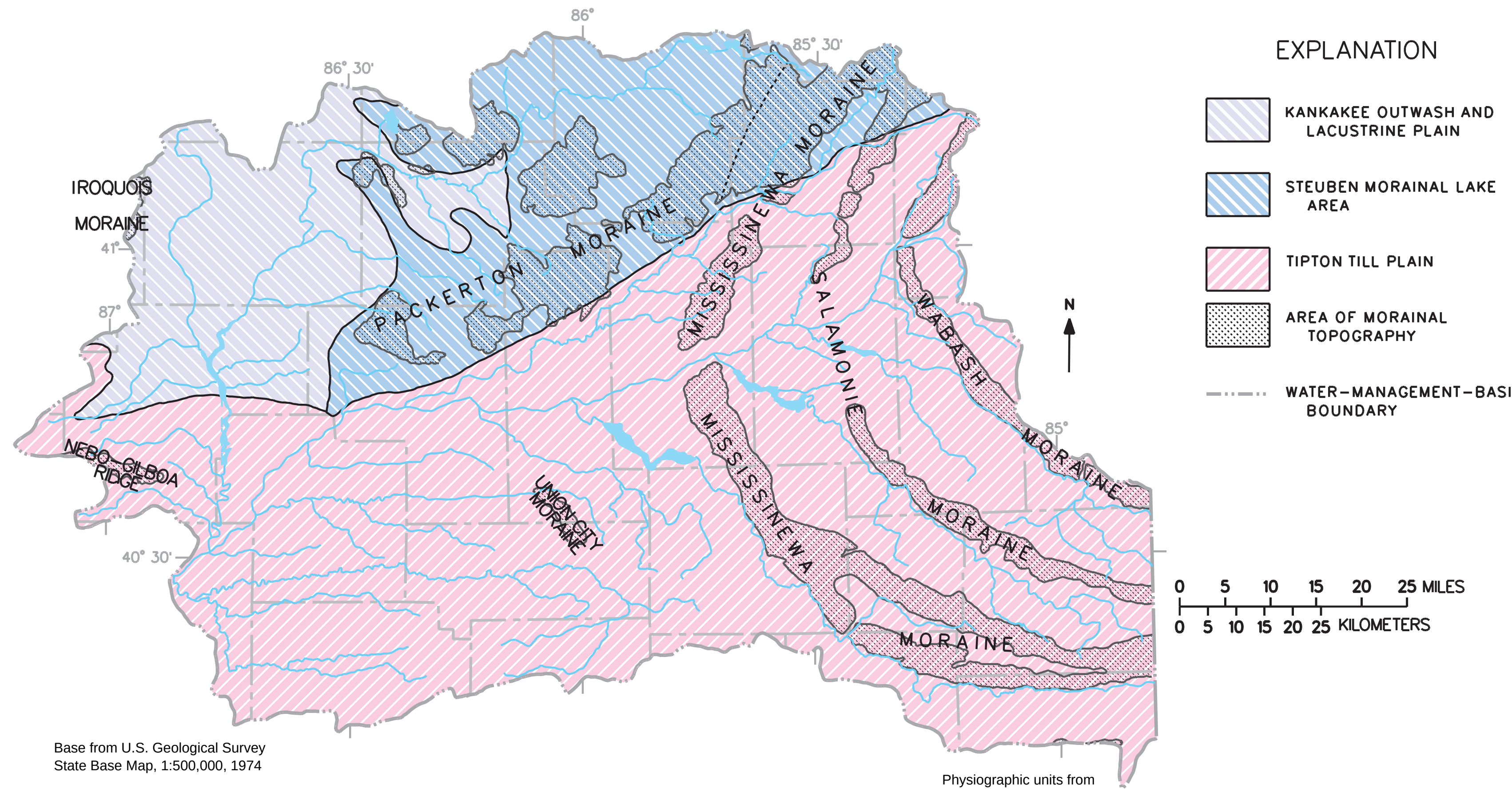


Figure 37. Physiographic units and moraines in the Upper Wabash River basin.

Surface-Water Hydrology

The Wabash River drains 32,910 mi^2 of Indiana, Illinois, and Ohio. Of the 23,921 mi^2 drained by the Wabash River within Indiana, 11,710 mi^2 are included in the three Wabash River management subbasins. Tributaries that are covered separately in this report drain the other 12,211 mi^2. The upper part of the Wabash River drains a total of 7,203 mi^2 of which 6,918 are in the Upper Wabash River management basin and 285 are in Ohio (Hoggatt, 1975, p. 2, 148, and 202).

The Wabash River begins in Mercer County, Ohio. From Mercer County, the Wabash River flows into Jay County, Ind. (fig. 36). Upstream from the Indiana-Ohio State line, the Wabash River drains 251 mi^2. Downstream from the State line, another 34 mi^2 of Ohio drainage eventually reaches the Wabash River by way of Limberlost Creek and the Mississinewa River (fig. 36).

This eastern part of the Wabash River basin is shaped like a shallow bowl as a result of continental glaciation. The glacially scoured landscape slopes northward from southern Randolph County to the Maumee River (sections 4E–4E′, fig. 34 and 5J–5J′, fig. 40). Moraines function as drainage-collection barriers on the slopes of the bowl. The moraines prevent tributaries draining the slope from reaching the center of the bowl. In the eastern part of the basin, the Mississinewa, Salamonie and Wabash Rivers drain these collection barriers, whereas the Loblolly-Limberlost (Adams and Jay Counties), Eightmile, and Rock Creeks (Wells County), plus many other small creeks, drain the slope. The streams follow the southern edge of the moraines in the southeast part of the basin, as shown in figure 37. Loblolly Creek is partially located in a surface trough that overlies the deeply buried Lafayette Bedrock Valley.

Upstream from the Indiana-Ohio State line, the Wabash River flows along the southern edge of the St. Johns Moraine (Ohio name for Salamonie Moraine of Indiana). At Fort Recovery, Ohio, 1 mile east of the State line, the Wabash River has cut across the St. Johns moraine and relocated against the Wabash Moraine. At the State line, the Wabash River is at an elevation of 835 ft above sea level.

Downstream from Bluffton, the Wabash River diverges from the Wabash Moraine and continues flowing northwest toward the Little River (Wabash-Erie Channel). The Wabash River flows on or near bedrock in this part of the basin. Huntington Reservoir, a flood control structure, regulates flow in the Wabash River upstream from the confluence of the Little River. The elevation of the Wabash River is 700 ft above sea level just downstream from Huntington Reservoir.

At Huntington, the Wabash River changes orientation, flowing west-southwest, and follows the Little River. The Little River (Wabash-Erie Channel) was the principal outflow channel for glacial Lake Maumee. Bedrock is exposed in the downstream end of the Little River channel. Downstream from Huntington, the Wabash River flows on bedrock. Terraces flanking the main channel are composed of stream-deposited sand and gravel.

Downstream from Huntington, the Salamonie River (fig. 36) is the next major tributary. The Salamonie River joins the Wabash River from the south bank at Lagro. A flood-control reservoir was constructed on the Salamonie River just upstream of the mouth. Downstream from Lagro to Richvalley (fig 36), the Wabash River flows on bedrock, commonly without terraces. Valley width in this stretch is slightly narrower than upstream from Lagro. This constriction may be because of the Mississinewa Moraine, through which the Wabash River cuts. At Richvalley, the Wabash River valley widens as it crosses the preglacial Lafayette Bedrock Valley.

Just downstream from Richvalley, the bottom of the Wabash River channel is at 635 ft above sea level, whereas the base of the Lafayette Bedrock Valley is at about 460 ft. At this location (section 5E–5E′, fig. 40), the buried drainage channel crosses under the Wabash River.

The Mississinewa River is the next principal tributary to the Wabash River, entering from the south bank (fig. 36). The city of Peru is 2 mi downstream from the mouth of the Mississinewa River. From Peru to Georgetown, the Wabash River flows west. Downstream from Peru, the bedrock surface rises, and the Wabash River again flows on rock with unconsolidated terraces. Pipe Creek is the next major tributary to join the Wabash River, also from the south bank.

At Logansport, the Eel River joins the Wabash River. The Eel River, which also began as a high-stage overflow drain for Lake Maumee, flows on unconsolidated materials along its entire course. The Eel River is the first major tributary entering the Wabash River from the north bank downstream of Huntington (fig. 36).

The Wabash River continues to flow on bedrock downstream from the mouth of the Eel River. At Logansport, terraces along the north side of the Wabash River are composed of unconsolidated material. Bedrock terraces, capped by as much as 60 ft of unconsolidated drift, form the south valley wall. At Georgetown (fig. 36), the orientation of the Wabash River changes again. Downstream of Georgetown, the Wabash River is oriented southwest.

The Wabash River flows on bedrock through most of Cass County and part of Carroll County. Just downstream from Georgetown, the Wabash River flows on unconsolidated deposits for several miles. At Delphi, the Wabash River exposes the top of a biohermal reef deposit, and the river temporarily flows on bedrock. Numerous bedrock exposures along the Wabash River are klintars, the exhumed tops of biohermal reef masses. Klintars form bedrock knobs that protrude above the surrounding land surface. In northeastern Tippecanoe County, the Wabash River flows near the bedrock surface with alluvial sand deposits in the channel.

In the area where Crooked Creek enters the Wabash River, the slope of the Wabash River channel decreases from greater than 2.5 ft/mi to less than 1.5 ft/mi. This change in slope is because of the large volumes of sediment carried into the Wabash River by the Eel and Tippecanoe Rivers. The Eel and Tippecanoe Rivers are the principal tributaries draining areas north of the Wabash River. Outwash-fan deposits adjacent to the Tippecanoe River (Tippecanoe Fan) have contributed large volumes of sediment to the Wabash River. This sediment loading begins choking the Wabash River channel more than 15 mi upstream of the Tippecanoe River.

The largest tributary to enter the Wabash River in the Upper Wabash River basin is the Tippecanoe River (fig. 36). Although the Tippecanoe River has no bedrock exposures in its channel, several tributaries, including Little Monon and Big Monon Creeks, flow on bedrock. Two reservoirs on the Tippecanoe River are located several miles upstream from the mouth. These reservoirs are for hydroelectric power and are not flood-control structures.

Continuing downstream, Wildcat Creek is the last tributary to enter the Wabash River in the Upper Wabash River basin. Wildcat Creek (fig. 36) enters the Wabash River from the southeast bank. From the Tippecanoe River downstream to Wildcat Creek, the Wabash River flows directly over the Battle Ground Lowland Section of the Lafayette Bedrock Valley (fig. 7), and the bedrock surface lies about 100 ft below the Wabash River in this area.

Geology

Bedrock deposits

Bedrock in the Upper Wabash River basin is composed of Paleozoic limestones, dolomites, sandstones and shales. Bedrock structure is dominated by the Cincinnati Arch (fig. 4), which plunges northwest across this basin. Along the axis of the Cincinnati Arch the rocks plunge from 4 to 13 ft/mi (0.04 to 0.14 degree) as indicated by a mapped Ordovician marker bed (Hasenmueller and Bassett, 1980c). The plunge of the axis is steepest in the northwestern part of the Upper Wabash River basin.

From the axis, bedrock dips both northeast into the Michigan Basin and southwest into the Illinois Basin (fig. 4). The dip of the bedrock away from the axis is slightly steeper than the plunge of the axis. Bedrock along the northeast-dipping flank has a maximum dip of 20 ft/mi (0.22 degree) in Kosciusko County, as indicated by a mapped Ordovician marker bed (Hasenmueller and Bassett, 1980c).

Most of the Upper Wabash River basin is on the northeast-dipping flank of the Cincinnati Arch. The Wabash River rises on the northeast flank of the arch and follows the plunge axis of the arch from the headwaters to Logansport. At Logansport, a structural bedrock sag in the crest of the arch, known as the Logansport Sag, allows the Wabash River to cross the axis of the Cincinnati Arch and drain toward the Illinois Basin (fig. 4).

Bedrock dips southwest in the part of the Upper Wabash River basin that includes Benton, Carroll, Clinton, Tippecanoe, and White Counties. The southwest-dipping flank of the Cincinnati Arch has a maximum dip of 17 ft/mi (0.18 degree) in southeast Tippecanoe County, as indicated by a mapped Ordovician marker bed (Hasenmueller and Bassett, 1980c). During part of the Paleozoic Era, the arch supported coral reef communities that are now deposits of carbonate rock. Throughout most of the Paleozoic Era, this anticline separated open seas to the northeast and southwest.

Although Paleozoic bedrock crops out at numerous locations in the Upper Wabash River basin, it is covered by drift in most places. Most bedrock exposures are near the Wabash River or its southern tributaries. The elevation of the buried bedrock surface ranges from just below 400 ft above sea level (Bruns and others, 1985a), at the base of a deep preglacial valley in Tippecanoe county, to about 1,050 ft above sea level (section 5J–5J′, fig. 40) in Randolph County near the Indiana-Ohio State line.

The age of bedrock exposed by preglacial erosion ranges from 315 to 440 million years (Palmer, 1983). Older Paleozoic rocks are present in the basin, but they were not exposed to post-Paleozoic erosion. A thick sequence of Cambrian sandstones, siltstones, shales, limestones, and dolomites overlies Precambrian igneous and metamorphic basement rocks. In the Upper Wabash River basin, the Cambrian rocks range from 2,000 to 3,500 ft in thickness. The Cambrian rocks are overlain by younger Ordovician sandstones, shales, and carbonate rocks. Ordovician rocks in the Upper Wabash River basin area are 1,000 to 1,400 ft thick.

The oldest rock to subcrop the drift in northeastern Indiana is the Maquoketa Group, an interbedded shale and limestone of Ordovician age. The subcrop of Upper Ordovician shales and limestones is present at the base of the Lafayette Bedrock Valley in the eastern one-third of the Upper Wabash River basin (fig. 38). The Geneva Segment of the Lafayette Bedrock Valley (fig. 7) is entrenched about 200 ft into the Ordovician rocks (section 5I–5I′, fig. 40).

Overlying the thinly bedded Upper Ordovician shale and limestone is a thick sequence of carbonate rocks, composed of limestones and dolomites. The carbonate rocks were deposited by marine organisms that lived in the seas during the Silurian and Devonian Periods. Silurian formations of the carbonate rock sequence are the Brassfield Limestone, Cataract Formation, Salamonie Dolomite, Pleasant Mills Formation, and the Wabash Formation. Overlying the Silurian formations is the Devonian Muscatatuck Group (fig. 38). Thick platform-reef deposits and associated debris are included within this carbonate rock sequence along the crest and flanks of the Cincinnati Arch.

The lithology of the Silurian-Devonian carbonate rock sequence is variable. Clayey carbonate rocks are more common than pure carbonate deposits. Dolomite has replaced limestone in some areas, and interbedded chert deposits are common in others. Bedded gypsum and anhydrite are found in the Devonian part of the carbonate rock sequence. The color of carbonate bedrock ranges from white to brown, and the texture ranges from micrite (a fine-grained crystalline precipitate) to bioclastic (a fossiliferous reef-framework detritus). Bedding ranges from thin to massive. Bedrock is nearly horizontal throughout most of this basin; however, steeply dipping beds (up to 45 degree dip) are observed locally in reef-flank deposits. Depositional environments ranged from deep-water marine to shallow-water marine and isolated tidal pools where evaporite deposits accumulated. Disconformities are present within Silurian deposits and at the Silurian-Devonian contact. These unconformities are nondepositional and erosional.

The Silurian and Devonian carbonate rock sequence attains a maximum thickness of 700 ft in northeastern Whitley County. Postdepositional erosion has thinned the carbonate rock sequence significantly in most of the basin. Because carbonate rocks are relatively resistant to weathering, they form the bedrock surface across the top of the Cincinnati Arch. Carbonate rocks are at the bedrock surface in about 75 percent of the Upper Wabash River basin (fig. 38). Some carbonate rocks are at the bedrock surface in every county within the Upper Wabash River basin.

After the deposition of carbonate rocks, a major change in sea level occurred. During the Devonian Period, sea level dropped relative to the arch, and the connection between the Michigan and Illinois Basins was interrupted. The Illinois and Michigan Basins both contain younger Devonian rocks, which display facies changes indicating shallowing seas and exposed land areas (Droste and Shaver, 1983, p. 24). The presence of sand indicates sandy coastal facies nearest to the arch edges. Kerogen-rich black shales were deposited in these anoxic basins. These carbonaceous shales are known as the New Albany Shale south of the Cincinnati Arch and as the Ellsworth and Antrim Shales north of the arch.

The New Albany Shale and equivalent shales were deposited during a 15 million year period (Palmer, 1983) extending from the Devonian Period into the early Mississippian Period. Although these fine-grained oil shales are as thick as 150 ft in the basin, the entire shale thickness remains in only a few subcrop locations in the Upper Wabash River basin. These formations have been thinned by erosion except where they are overlain by younger rocks.

Overlying the New Albany Shale is a thin limestone, known as the Rockford Limestone. Where present, the Rockford Limestone is less than 22 ft thick (Shaver and others, 1986, p. 124). In this basin, the top and bottom contacts of the Rockford Limestone are conformable and sharp. Both overlain and underlain by shales, this thin limestone is an excellent Lower Mississippian marker bed. This limestone has a uniform lithologic texture over a large area of Indiana and Illinois.

Where present, the Rockford Limestone is overlain by silts and shales of the Borden Group. The Borden Group shales are the youngest Mississippian subcrops in the Upper Wabash River basin. When deposited, the Borden Group probably was more than 500 ft thick in this area. Now, because of postdepositional erosion, the Borden Group is generally less than 50 ft thick in Benton, Clinton, Tippecanoe, and White Counties. In the Upper Wabash River basin, the Borden Group subcrop area covers less than 100 mi^2 and is buried under 15 ft or more of drift. In this basin, the New Providence Shale appears to be the only formation within the Borden Group that has not been eroded. The New Providence Shale is primarily a blue-gray shale. In this basin, drift unconformably overlies the Borden Group; the contact is characterized by moderate relief.

The youngest rocks in the Upper Wabash River basin were deposited during the early Pennsylvanian Period. In Benton and White Counties, a shaley sandstone of the Raccoon Creek Group (Shaver and others, 1986, p. 120 and 121) forms remnant caps overlying older rocks. The rocks are medium- to coarse-grained sandstones in alluvial-channel deposits containing carbonaceous shale lenses (S.J. Keller, Indiana Geological Survey, oral commun., 1990). These isolated subcrops of Pennsylvanian rock are generally less than 30 ft thick.

The Pennsylvanian rocks in the Upper Wabash River basin unconformably overlie Mississippian and Devonian rocks. After the deposition of the Mississippian rocks, a major erosional event removed most Mississippian rocks from this basin. At the northern end of hydrogeologic section 5A–5A′ (fig. 40), more than 1,300 ft of Upper Mississippian and Lower Pennsylvanian stratigraphic section is missing (Gray, 1979, p. K12). Hydrogeologic section 5A–5A′ (fig. 40) indicates erosion of the New Albany Shale in the Wolcott area prior to the deposition of the Raccoon Creek Group. The hiatus (period of missing record) between these rocks represents more than 35 million years. There are no younger Pennsylvanian bedrock units in this basin, although younger Paleozoic deposits have been found in Indiana and elsewhere.

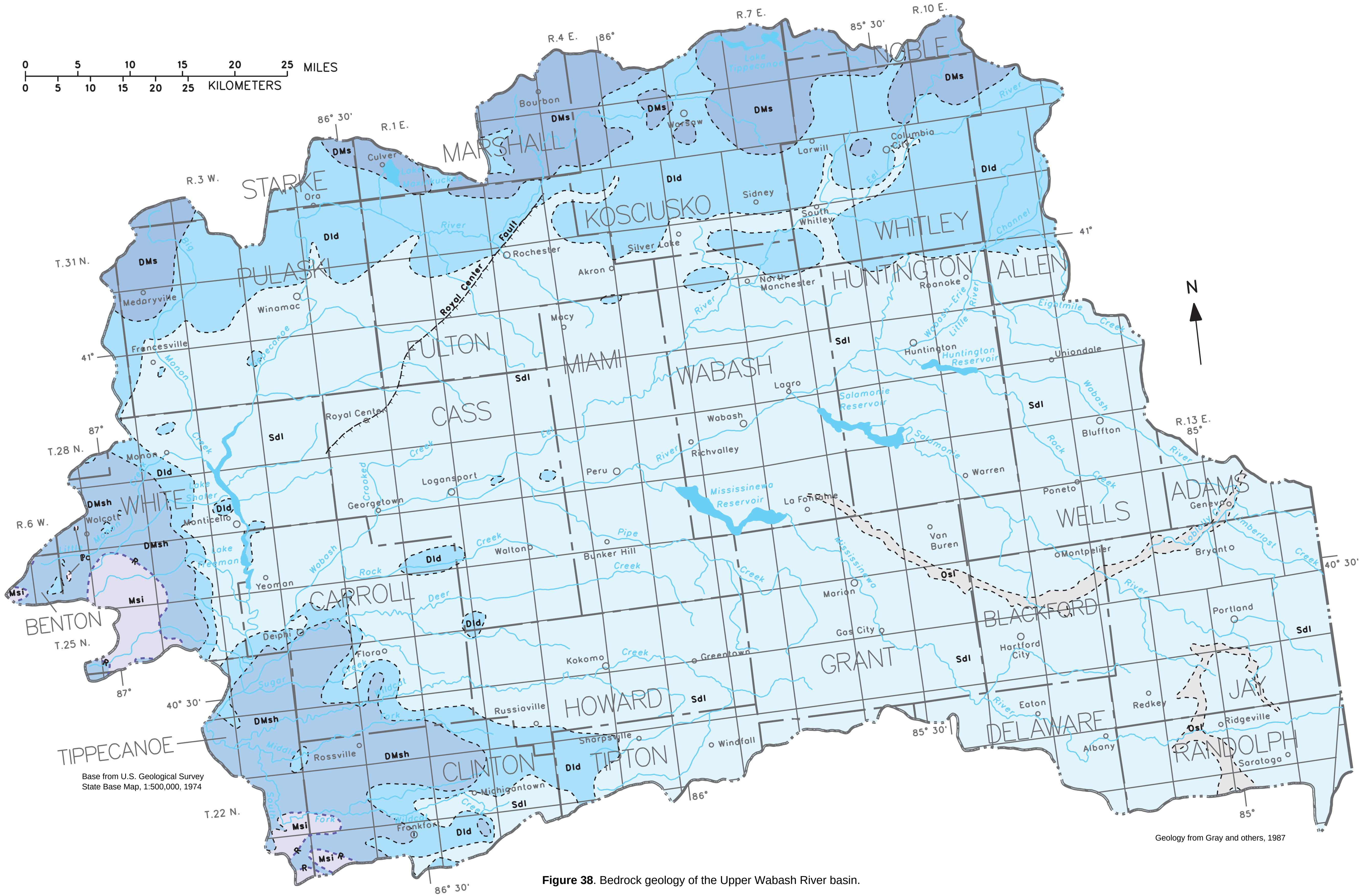


Figure 38. Bedrock geology of the Upper Wabash River basin.

EXPLANATION

- **Pc** — PENNSYLVANIAN COMPLEXLY INTERBEDDED SHALE AND SANDSTONE, WITH THIN BEDS OF LIMESTONE AND COAL-- Composed of the Racoon Creek Group
- **Msi** — MISSISSIPPIAN SILTSTONE AND SHALE WITH MINOR SANDSTONE AND DISCONTINUOUS LIMESTONE-- Composed of the Borden Group
- **-R-** — ROCKFORD LIMESTONE
- **DMsh** — DEVONIAN AND MISSISSIPPIAN SHALE-- Composed of the New Albany Shale
- **DMs** — DEVONIAN AND MISSISSIPPIAN SHALE-- Composed of the Antrim and Ellsworth Shales
- **Dld** — DEVONIAN LIMESTONE AND DOLOMITE-- Composed of the Muscatatuck Group
- **Sdl** — SILURIAN DOLOMITE AND LIMESTONE-- Composed of the Wabash and Pleasant Mills Formations, and the Salamonie Dolomite, Cataract Formation, and Brassfield Limestone
- **Osl** — ORDOVICIAN SHALE AND LIMESTONE-- Composed of the Maquoketa Group
- NORMAL FAULT-- Hachures on downthrown side. Dashed where approximately located
- GEOLOGIC CONTACT-- Dashed where approximately located
- WATER-MANAGEMENT-BASIN BOUNDARY

Unconsolidated deposits

Glacial ice invaded Indiana several times during the Pleistocene Epoch (1 million to 10,000 years ago). Moving from several spreading centers in Canada, glaciers followed physiographic lowlands and major valleys to reach Indiana (fig. 8). The Huron-Erie Lobe moved into northeastern Indiana from the Lake Erie and Lake Huron basins several times. The Huron-Erie Lobe followed a bedrock lowland developed on Devonian and Mississippian shales. Synchronously, glacial ice moved south out of the Lake Michigan basin several times. The Lake Michigan Lobe also followed a physiographic lowland developed on the same Devonian and Mississippian shale bedrock.

A third lobe of ice, the Saginaw Lobe, filled the area between the other two lobes. This lobe moved through the Saginaw Bay area of Michigan. Glaciers competed for space in the Upper Wabash River basin several times. The Saginaw Lobe moved southward until its path was blocked by the Lake Michigan Lobe on the west and the Huron-Erie Lobe on the south and east. With its westward path blocked, the Huron-Erie Lobe advanced southward onto the carbonate bedrock platform in central and eastern Indiana.

Glaciers have followed these glacial flow paths into Indiana several times. More is known about the most recent glacial advance, the Wisconsinan glacial stage, than about earlier advances. This is primarily because of the presence of the Wisconsinan drift at the land surface. Many drift deposits from earlier glacial periods have been scoured and incorporated into younger sediments. Others are buried under younger deposits.

During each advance, thick glacial ice covered the land. Glacial ice in the Upper Wabash River basin is estimated to have been several thousand feet thick (Harrison, 1958, p. 84). In addition to tremendous volumes of water, glaciers also transported huge volumes of sediment into Indiana. Glacially transported sediment choked drainages and aggraded channels.

When the first pre-Illinoian glacial lobe reached Indiana from the north and northeast and spread out onto the carbonate bedrock platform, it encroached upon a major valley system known as the Lafayette Bedrock Valley (fig. 7). This preglacial channel was entrenched more than 350 ft into the nearly horizontal Paleozoic sediments. Sediment from the advancing glacier blocked this valley in at least two places. In eastern Indiana, a gray loam till and other sediments filled the valley from “rock rim to rock rim,” whereas a claystone-bearing red till partially filled the valley from east-central to west-central Indiana (Bleuer, 1989, p. 6). The red till has been dated at greater than 730,000 years old (Bleuer, 1989, p. 7) and is among the oldest tills in the valley. Currently, the entire Lafayette Bedrock Valley is filled with glacial sediments.

Within a physiographic area, the surficial unconsolidated deposits generally have the same depositional history. Because of this regional similarity, the unconsolidated geology will be discussed by physiographic regions (fig. 37). Exceptions to this general rule are common, however, especially in areas underlain by the Lafayette Bedrock Valley.

The first physiographic area, the Steuben Morainal Lake Area (fig. 37), is located north of the Eel River and east of Logansport, and it includes the Tippecanoe River basin upstream of Monterey. During the Late Wisconsinan, the Huron-Erie Lobe of glacial ice moved west-southwest into Indiana from the Lake Erie basin as the Saginaw Lobe moved south-southwest into Indiana from the Saginaw Bay area. When the two lobes met, they blocked each other and stagnated. After stagnation, the Saginaw Lobe was partially overrun by the Huron-Erie Lobe.

A thick deposit of glacial drift, herein called the “moraine complex,” was built up by repeated glacial advances of the two lobes. The moraine complex is composed of unsorted clay, silt, sand, gravel, and boulders in irregular deposits; drift is more than 250 ft thick in this area (fig. 39). The moraine complex includes areas depicted as Packerton Moraine and Mississinewa Moraine in figure 37 and in hydrogeologic sections 5C–5C′ to 5H–5H′ (fig. 40).

As the Saginaw and Huron-Erie Lobes competed for space, they formed very complicated geologic deposits. Any original depositional structure within the drift of the moraine complex was obliterated by glacial thrusting. Within the moraine complex, blocks of till were shoved together by glacial ice. Sand and gravel were carried into available spaces between till blocks by meltwater. Numerous kettle lakes are present in this area; the depressions for these lakes resulted from the burial of glacial ice.

The second physiographic area exhibiting distinct unconsolidated deposits corresponds with the Kankakee Outwash and Lacustrine Plain (fig. 37). This area is northwest of the Packerton Moraine and north of the Wabash River. The Tippecanoe River currently drains this area, but this was not always the case.

During the retreat of the Saginaw Lobe, meltwater drained from Indiana by way of the Kankakee River drainage basin. This meltwater carried large volumes of sediment, which choked the streams draining the area. Surficial sand deposits, some more than 50 ft thick, were laid down. As the ice terminus shifted and meltwater volume varied, however, the streams draining this area changed routes several times.

Stream piracy has been active in the development of the Tippecanoe River and Yellow River drainage basins. (The Yellow River is not in the Upper Wabash River basin; it is a tributary of the Kankakee River.) Several glacial sluiceways connected the Yellow River with the Tippecanoe River basin. At Ora, on the Pulaski County-Starke County line (fig. 36), the basin divide between the Tippecanoe River and Yellow River is only 15 ft above the normal flow elevation of the Tippecanoe River. Topographic relief and potentiometric relief are very low in this part of the basin.

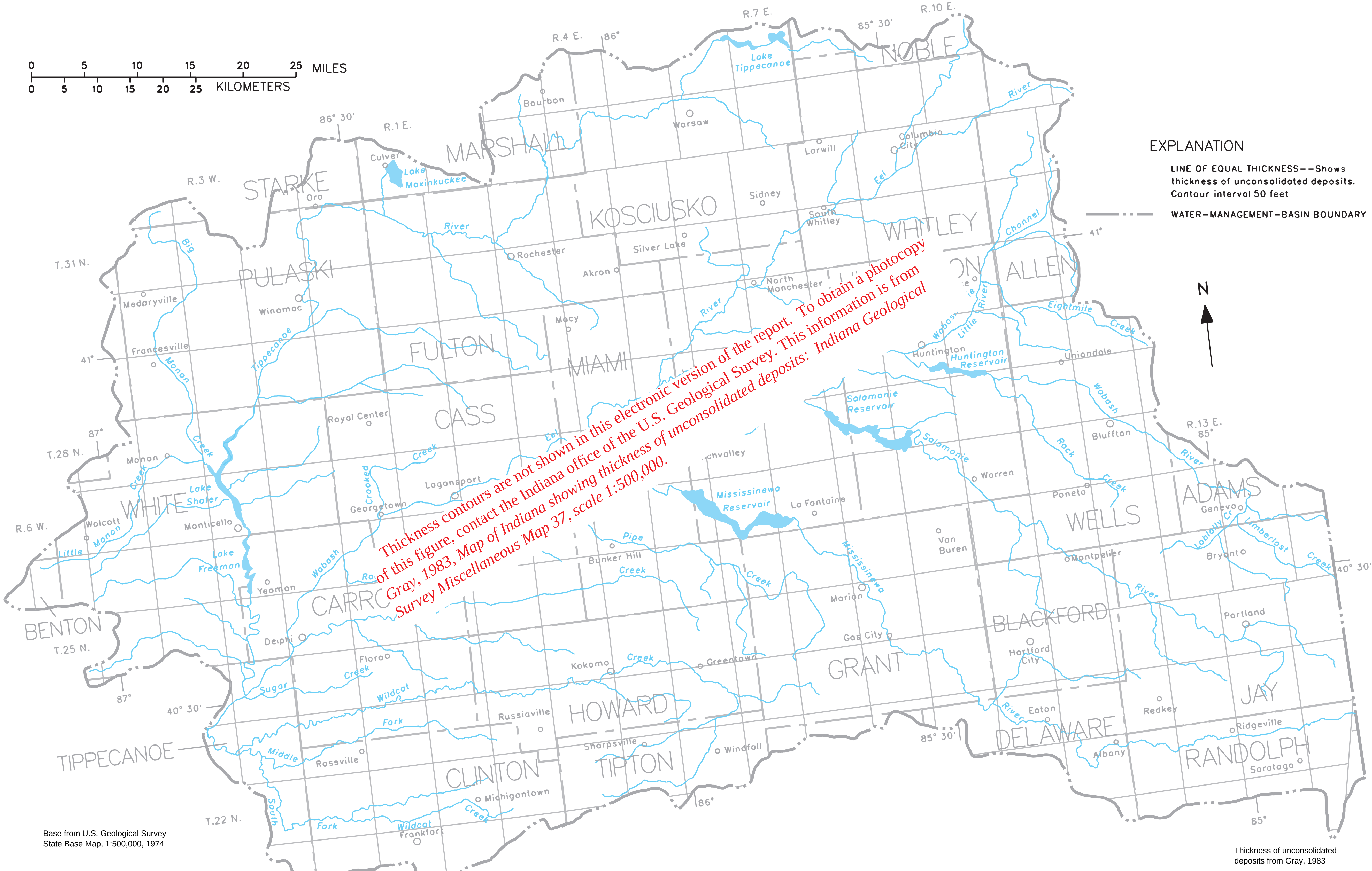


Figure 39. Thickness of unconsolidated deposits in the Upper Wabash River basin.

The third physiographic area of similar unconsolidated geology is south of the Eel River and east of Peru. This is the northeastern part of the Tipton Till Plain, which is covered with clay-loam till. These till deposits have been radiocarbon dated as more than 14,000 years old (Wayne, 1963, p. 44). In the Upper Wabash River basin, nearly all surface sediments south of the Eel River are of glacial origin and are considered to be part of the Lagro Formation of Late Wisconsinan age (Gray, 1989). The Mississinewa, Salamonie, and Wabash Moraines form arc-shaped ridges across this area (fig. 37).

South of the Eel River, till covers the broad Silurian carbonate bedrock platform. In the area between the Eel River and the Wabash-Little River Channel, drift thickness is greater than 150 ft (fig. 39). Lagro till composition ranges from 35 to 55 percent clay, 35 to 50 percent silt, and 10 to 30 percent sand by weight (Gooding, 1973, p. 8). Clay content in this till sheet is inversely proportional to sand content, with the combined weight of clay and sand equaling about 65 percent of the total weight.

The area south of Huntington and east of Peru was scraped clear of most pre-Wisconsinan drift, and the Lagro drift sheet is commonly less than 50 ft thick (fig. 39). Exceptions to the thin drift are areas underlain by the Lafayette Bedrock Valley (fig. 7). Drift greater than 400 ft thick is common within the buried preglacial valley (fig. 39). A basal sand and gravel overlies much of the bedrock south of the Wabash River (sections 5H–5H′ to 5J–5J′, fig. 40). This basal deposit is generally less than 10 ft thick and hydrologically connects the carbonate bedrock and the drift.

In the area of thin drift, erosion has removed the thin drift from the valleys of the large streams. The Wabash, Mississinewa and Salamonie Rivers flow on, or near, the bedrock. Exceptions are where the Wabash River crosses buried drainage channels. Two examples of this are (1) more than 300 ft of unconsolidated deposits underlie the Wabash River at Geneva and (2) more than 175 ft of unconsolidated deposits underlie the Wabash River just upstream from the mouth of the Mississinewa River (section 5E–5E′, fig. 40).

The fourth and final area of distinct unconsolidated deposits in the Upper Wabash River basin is south of the Wabash River and west of the Mississinewa River. This area corresponds to the part of the Tipton Till Plain that is covered by the Trafalgar Formation of Late Wisconsinan age (Gray, 1989). This area is underlain by buried moraines and thick deposits of drift. Drift thickness increases southward from the Wabash River and generally ranges from 0 to 200 ft in this area, although more than 350 ft of drift is found south of Frankfort, Clinton County (fig. 39). (See hydrogeologic section 5C–5C′, fig. 40.)

In this part of the Tipton Till Plain, the till is composed of an uncemented silty, sandy, calcareous till containing abundant pebbles and cobbles with scattered beds and lenses of silt, sand, and gravel (Shaver and others, 1970, p. 176-178). Drift originated from a northeastern (Huron-Erie Lobe) source. East of Pipe Creek, the Trafalgar Formation is covered by the younger Lagro Formation, both of Late Wisconsinan age (Wayne, 1963, p. 48).

Aquifer Types

Ten hydrogeologic sections in the Upper Wabash River basin (fig. 40) were constructed for this atlas. All are oriented perpendicular to the Wabash River. Eight of these hydrogeologic sections (5C–5C′ to 5J–5J′, fig. 40) are oriented south-north parallel to township boundaries and are 12 mi apart. The two westernmost hydrogeologic sections (5A–5A′ and 5B–5B′, fig. 40) are oriented south-southeast to north-northwest (fig. 36). Hydrogeologic sections 5A–5A′, 5B–5B′, and 5C–5C′ (fig. 40) are approximately 20 mi apart on their northern ends and 6 mi apart on their southern ends. The average density of logged wells plotted along the sections is 1.4 wells per mile. The 10 hydrogeologic sections (5A–5A′ to 5J–5J′) have a combined total length of 594 miles and a total of 833 plotted wells.

Additional bedrock-altitude information used in the hydrogeologic sections was from Bruns and others (1985a, 1985b, 1985c). Bedrock-stratigraphy information was supplemented by Bassett and Hasenmueller (1979, 1980) and Hasenmueller and Bassett (1980a, 1980b, 1980c). Other supplemental bedrock information was obtained from Bassett and Keith (1984) and Cazee (1988).

A map showing the extent of aquifers in the Upper Wabash River basin (fig. 41) was constructed by use of the hydrogeologic sections. Additional information for the aquifer map was obtained from the “Quaternary geologic map of Indiana” (Gray, 1989) as well as other studies referenced elsewhere in this section.

The aquifer map shows six types of aquifers used in the Upper Wabash River basin. Of these six aquifer types, four are restricted to the extensive unconsolidated deposits. These include surficial sand and gravel aquifers, buried sand and gravel aquifers, discontinuous sand and gravel aquifers in isolated deposits, and deep bedrock valleys, which may contain sand and gravel aquifers. A fifth aquifer type is carbonate bedrock of Silurian and Devonian age or of Early Mississippian age. The Silurian and Devonian carbonate rock is the primary aquifer used in about 50 percent of the basin. In another 25 to 35 percent of the basin, the carbonate bedrock aquifer is mapped where it is within 300 ft of the land surface but is not commonly used for water supply. The sixth aquifer type shown in figure 41, an upper weathered-bedrock aquifer in shale, is present in the extreme western part of the basin. Because the aquifer covers such a small part of the basin, it is not discussed in this section. Information on the upper weathered-bedrock aquifer is provided in the sections on the Kankakee River and Middle Wabash River basins in this report.

Characteristics of the five primary aquifer types in the Upper Wabash River basin are listed in table 7. Differences between the types of sand and gravel aquifers are not indicated on the hydrogeologic sections.

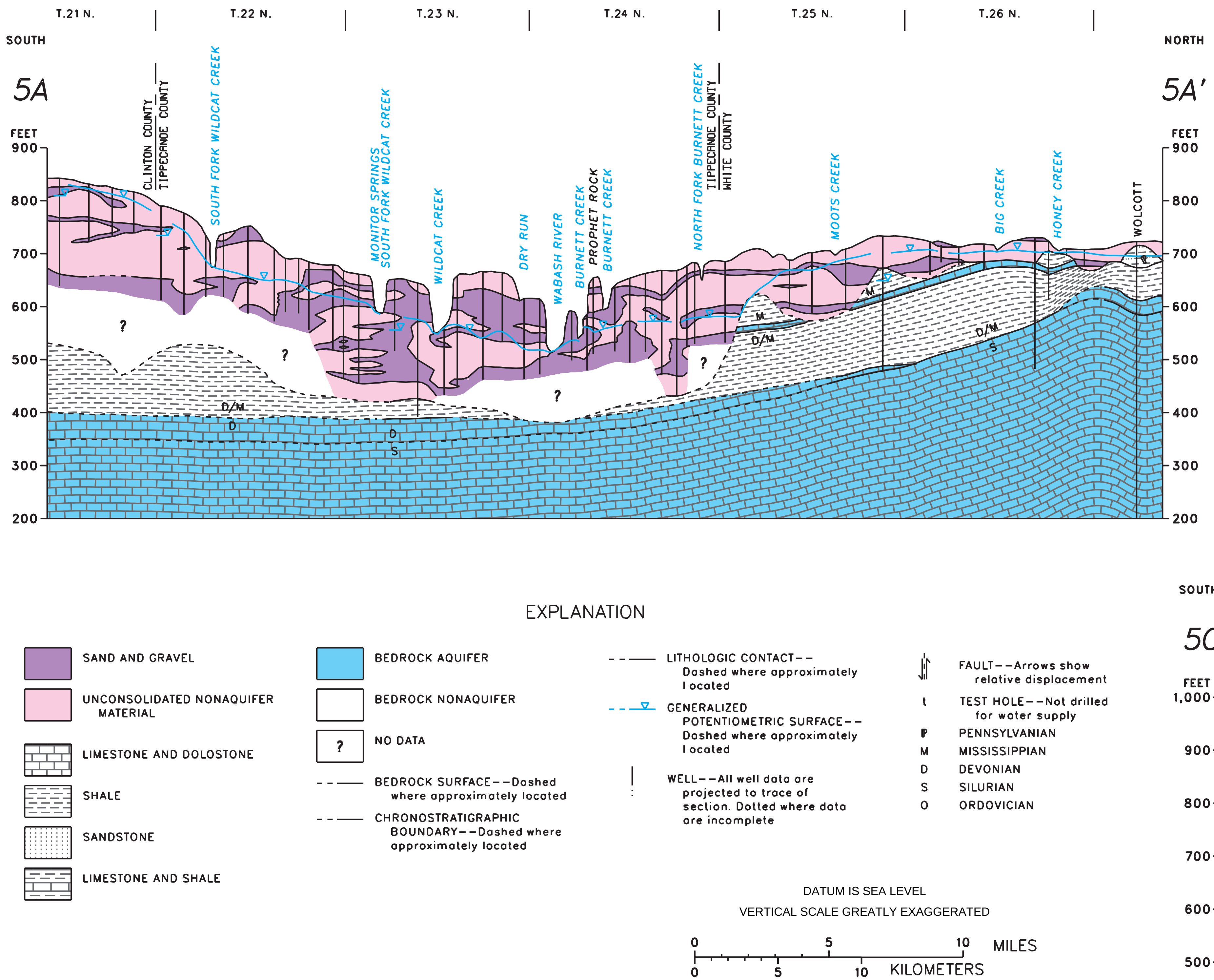
Unconsolidated Aquifers

Surficial Sand and Gravel Aquifers

Surficial sand and gravel has been deposited in three environments: (1) outwash plains and valley trains where sediment was deposited by glacial meltwaters; (2) alluvial environments where sediment is being deposited by present-day streams; and (3) sand dunes where sediment was deposited by the wind. Most of the surficial sand and gravel deposits in the Upper Wabash River basin are glacial in origin. Glacial meltwater carried sand and gravel away from the margin of active glaciers. Outwash-plain and valley-train deposits formed along glacial drainage routes. Large outwash deposits of unconsolidated sand and gravel are present along the Eel River, Tippecanoe River and along the Wabash River downstream from Delphi. Tremendous volumes of sediment were brought into the Wabash River by the Eel and Tippecanoe Rivers.

Outwash-plain deposits blanket more than 600 mi^2 of the Upper Wabash River basin with sand and gravel. Most surficial outwash-plain deposits are near the Tippecanoe River. These outwash-plain deposits form a blanket of sand from 20 to 80 ft thick. Outwash-plain deposits are mapped north of Lake Shafer at Buffalo (section 5B–5B′, fig. 40). Here, the surficial deposits are from 20 to 50 ft thick and as much as 720 ft above sea level. Surficial deposits of sand and gravel, as much as 80 ft thick, are mapped (section 5C–5C′, fig. 40) from the Tippecanoe River north to Lake Houghton and the basin boundary.

Beginning at Delphi, terraced valley-train sands and gravels are present along the Wabash River. These valley-train deposits form two terraces above the current flood plain. (See McBeth, 1902, p. 237.) The terraces formed at the time the glaciers were melting. The width of the outwash deposits range from 1.5 to 2.5 mi upstream from Logansport, and from 2 to 3 mi downstream from Delphi. Large flow volumes during glacial time scoured the shallow bedrock and prevented the accumulation of major unconsolidated deposits along the Wabash River upstream from Logansport.



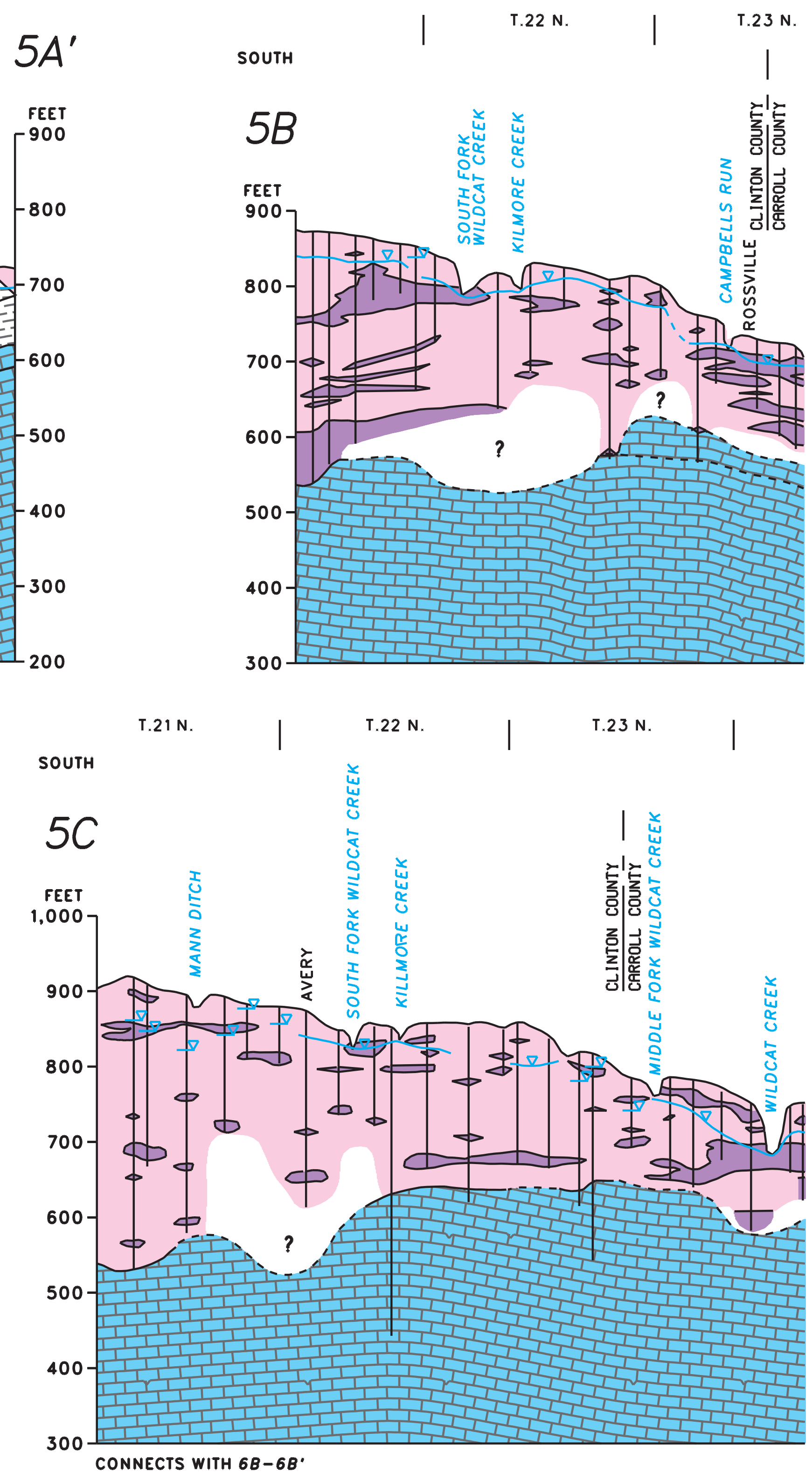
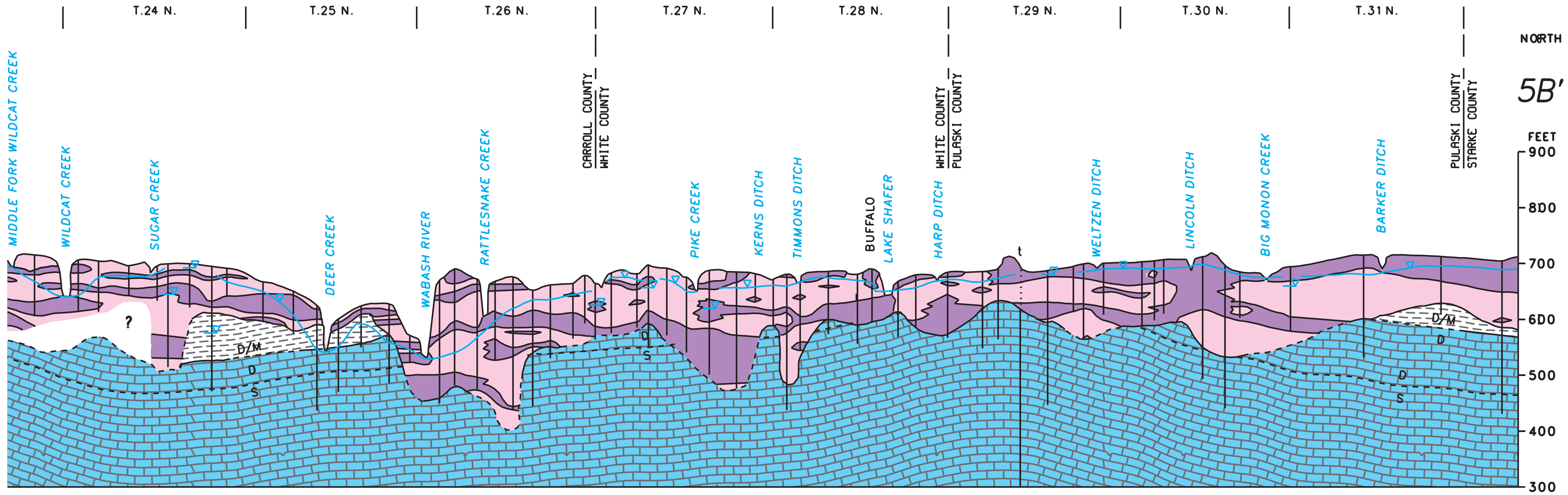
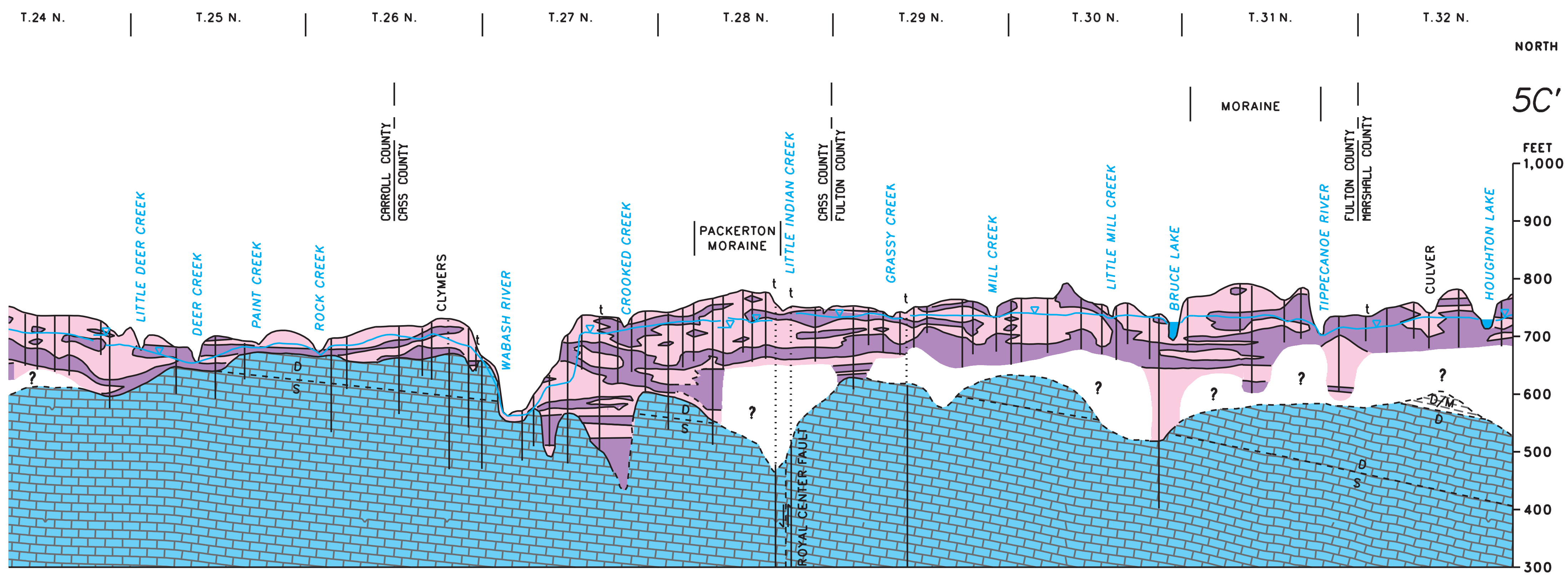


Figure 40. Hydrogeologic sections *5A–5A′* to *5J–5J′* of the Upper Wabash River basin.

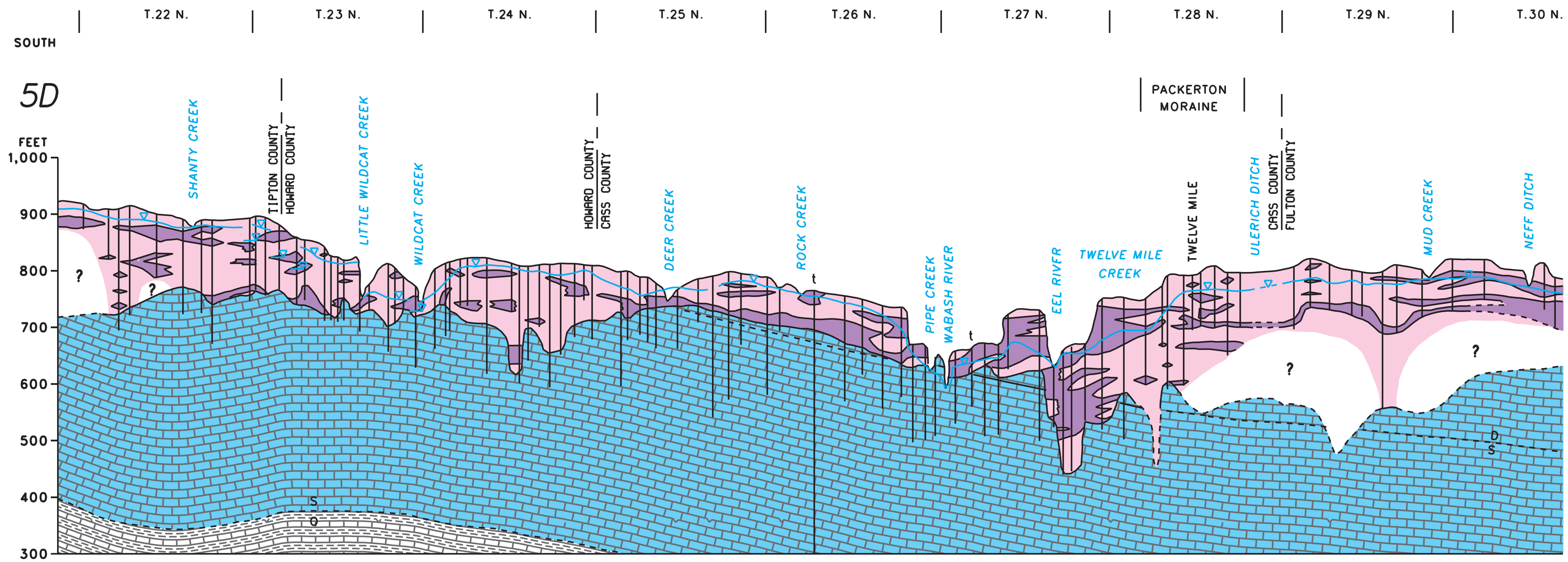


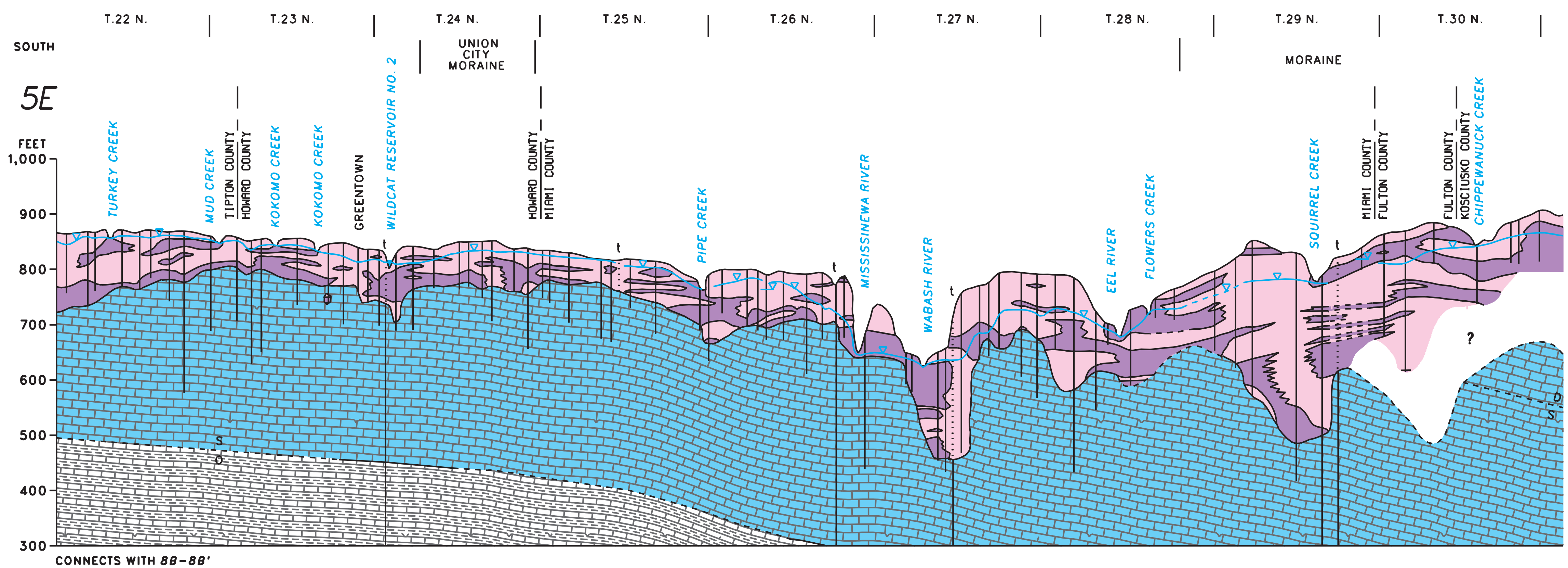
T.24 N.
T.25 N.
T.26 N.
T.27 N.
T.28 N.
T.29 N.
T.30 N.
T.31 N.
NORTH
5B′
CARROLL COUNTY
WHITE COUNTY
WHITE COUNTY
PULASKI COUNTY
PULASKI COUNTY
STARKE COUNTY
FEET
900
800
700
600
500
400
300
MIDDLE FORK WILDCAT CREEK
WILDCAT CREEK
SUGAR CREEK
DEER CREEK
WABASH RIVER
RATTLESNAKE CREEK
PIKE CREEK
KERNS DITCH
TIMMONS DITCH
BUFFALO
LAKE SHAFER
HARP DITCH
WELTZEN DITCH
LINCOLN DITCH
BIG MONON CREEK
BARKER DITCH
D/M
D
S

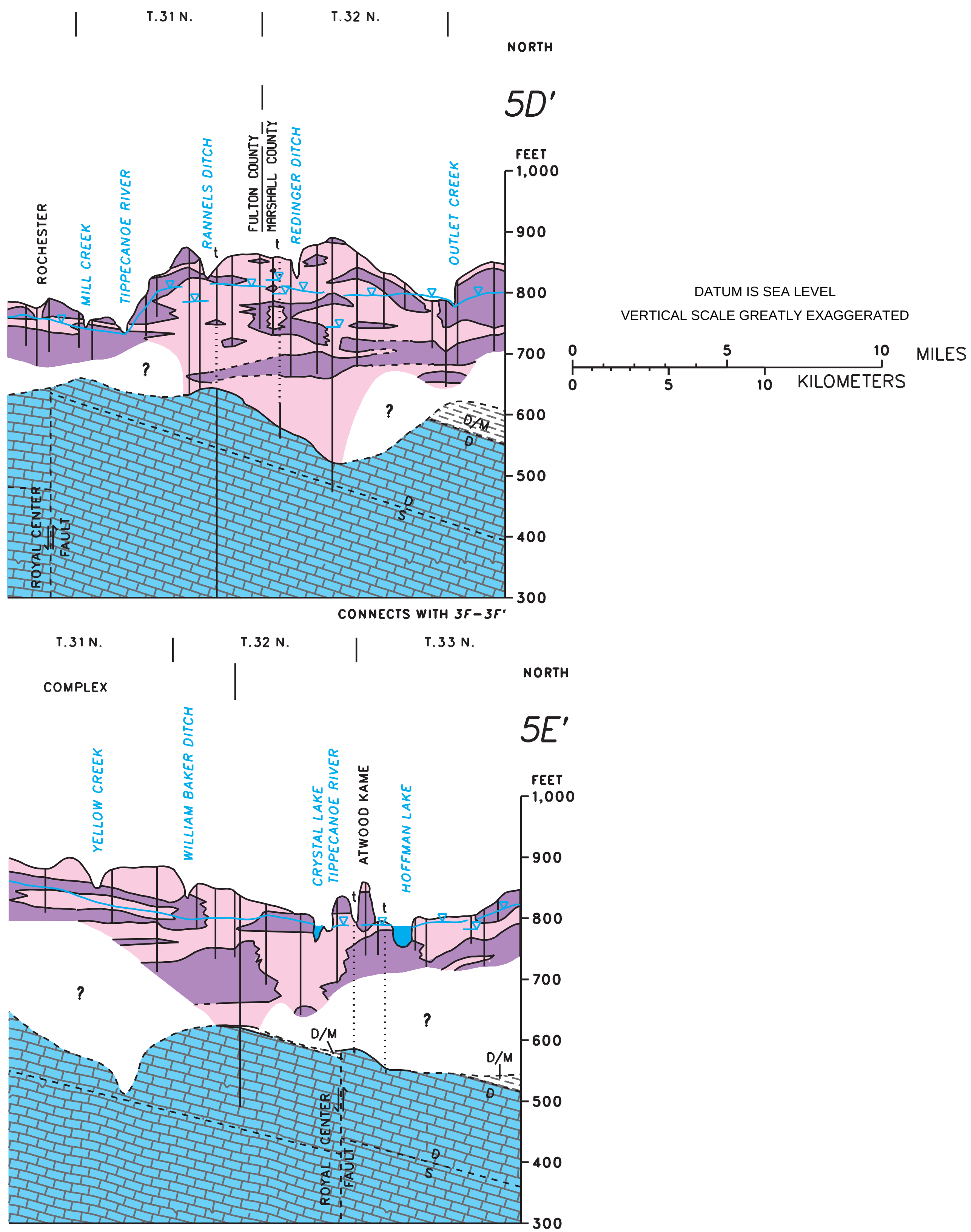


T.24 N.
T.25 N.
T.26 N.
T.27 N.
T.28 N.
T.29 N.
T.30 N.
T.31 N.
T.32 N.
NORTH
5C′
MORAINE
CARROLL COUNTY
CASS COUNTY
CASS COUNTY
FULTON COUNTY
FULTON COUNTY
MARSHALL COUNTY
PACKERTON MORAINE
FEET
1,000
900
800
700
600
500
400
300
LITTLE DEER CREEK
DEER CREEK
PAINT CREEK
ROCK CREEK
CLYMERS
WABASH RIVER
CROOKED CREEK
LITTLE INDIAN CREEK
GRASSY CREEK
MILL CREEK
LITTLE MILL CREEK
BRUCE LAKE
TIPPECANOE RIVER
CULVER
HOUGHTON LAKE
ROYAL CENTER FAULT
D/M
D
S
CONNECTS WITH 3E–3E′

Figure 40. Hydrogeologic sections *5A–5A′* to *5J–5J′* of the Upper Wabash River basin—Continued.







In Indiana, surficial sand and gravel deposits commonly contain large volumes of recoverable ground water, especially in outwash materials. Water levels in surficial aquifers are generally within 30 ft of the land surface, but are deeper adjacent to the Wabash River downstream from Delphi (section 5A–5A′, fig. 40). Terrace deposits in this area have deep, unconfined water tables. Because surficial aquifers are easily contaminated, some surface deposits are no longer suitable for potable ground-water production. In Kosciusko County, 30 of 83 private supply wells with nitrate contamination tap surficial, unconfined aquifers (State of Indiana, 1989, p. 9-11).

Alluvial deposits are another type of surficial aquifer that is common in the Upper Wabash River basin. Composed of reworked outwash sand and gravel and deposited adjacent to river channels, alluvial deposits commonly form a veneer on bedrock or drift. Deposits of alluvium are generally less than 30 ft thick and are covered by less than 10 ft of nonaquifer material.

The largest alluvial aquifers in the basin are found within the outwash deposits along the Eel River and along the Wabash River downstream from Delphi. Downstream from Delphi, the width of the alluvial deposits is from 0.5 to 1 mi along the Wabash River. Although bedrock reappears adjacent to the river in some areas, the alluvial deposits are continuous from Delphi downstream 330 mi to the mouth.

Sand dunes are another common type of surficial unconsolidated deposit in the Upper Wabash River basin. Wind has reworked both alluvial and outwash deposits into sand dunes. Two of the largest dunes are shown (T. 29 N. and 30 N.) in hydrogeologic section 5B–5B′ (fig. 40). These dunes stand 20 to 30 ft above the outwash plain. Dune deposits are very fine grained and may be above the water table, which makes dune-sand deposits a poor source of ground-water.

Buried Sand and Gravel Aquifers

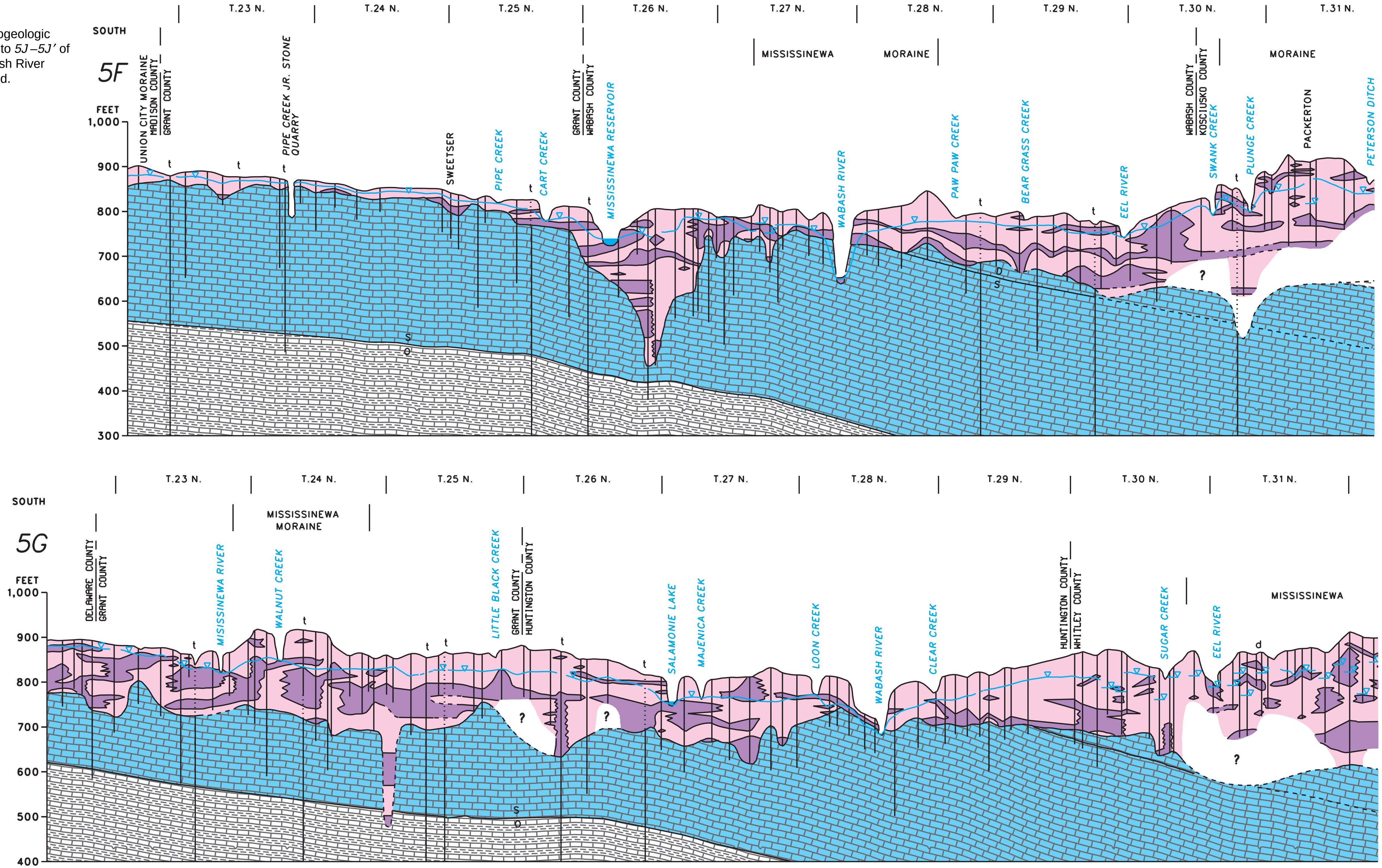
Most of the sand and gravel deposits in the Upper Wabash River basin are buried (fig. 41). Forming general horizons within the drift, buried sand and gravel aquifers formerly were isolated- to reticulating-fan, subice channel, outwash-plain, and valley-train deposits. Buried aquifers are mapped as continuous although they were not deposited uniformly. Variations in the aggradational environment resulted in large variations of intertill aquifer thickness and distribution. Additional disruption of deposits resulted from glacial scour and shoving during burial. Most buried aquifers were originally surficial deposits, which have now been enclosed within the drift. Buried aquifers are covered by silty, clay-loam to loam tills and loess in the Upper Wabash River basin. The exact location and elevation of buried aquifers is unpredictable, as is their degree of interconnection.

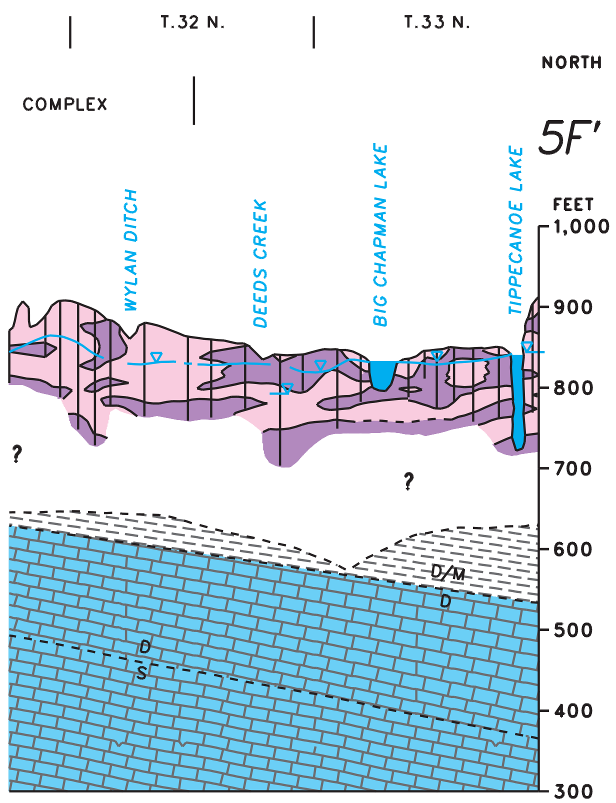
In the Upper Wabash River basin, numerous intertill sand and gravel deposits have been exposed by stream erosion. Examples are shown along the Wabash River (sections 5A–5A′ to 5F–5F′, fig. 40); the Salamonie River (sections 5G–5G′ to 5J–5J′, fig. 40); the Mississinewa River (sections 5E–5E′ to 5J–5J′, fig. 40); the Eel River (sections 5D–5D′ and 5E–5E′, fig. 40); the Tippecanoe River (sections 5C–5C′ to 5E–5E′, fig. 40); Pipe Creek (sections 5D–5D′ and 5E–5E′, fig. 40); and Wildcat Creek (sections 5A–5A′ to 5C–5C′, fig. 40).

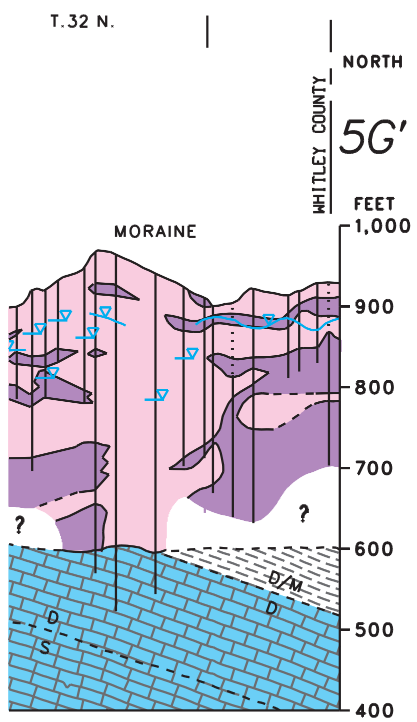
In addition to the buried sand and gravel deposits exposed along the major streams, numerous buried sand and gravel aquifers are exposed by tributary streams throughout the area. The hydrogeologic sections indicate the connection between surface drainage and the buried sand and gravel aquifers. Except during high stream stage, ground water commonly discharges to the streams.

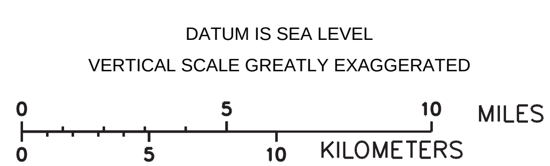
South of the Wabash River and northwest of Kokomo, buried aquifers are common and fairly extensive. In many areas, a basal aquifer is present at the interface of bedrock and drift. North of the Wabash River in the Upper Wabash River basin most ground-water production comes from buried sand and gravel aquifers. Ground water in buried aquifers is generally confined. Large yields of water, ranging from 20 to 1,350 gal/min are available from buried aquifers in the Upper Wabash River basin. The largest yields available are in Kosciusko, Noble, and Whitley Counties (Clark, 1980, p. 33).

Figure 40. Hydrogeologic sections *5A–5A′* to *5J–5J′* of the Upper Wabash River basin—Continued.









Bleuer and Moore (1978, p. 43) report that, in a study for Allen County, water from the glacial aquifers has higher dissolved concentrations of bicarbonate, iron, and zinc than water from the carbonate bedrock aquifer. Water in wells sampled from glacial aquifers contained four times as much dissolved iron as water in wells sampled from the carbonate bedrock aquifer. None of these constituents present a health hazard in concentrations reported.

Numerous deposits of cemented sand and gravel have been found in the Upper Wabash River basin. Lithified Holocene deposits have formed from the chemical deposition of calcium carbonate and hydrous iron oxides dissolved in ground water. Deposition of the cementing agents occurs where confined aquifers are exposed to the atmosphere, as in aquifer outcrops along streams. One notable occurrence of a cemented sand and gravel deposit is Prophet's Rock, at the Tippecanoe Battleground site, Battle Ground, Ind. Prophet's Rock (T. 24 N.), shown on hydrogeologic section 5A–5A′ (fig. 40), is an outcrop of sand, gravel, and cobbles cemented by calcium carbonate.

Discontinuous Sand and Gravel Aquifers

Two main areas of discontinuous buried sand and gravel aquifers are shown on the aquifer map (fig. 41). Within these areas, aquifers are small, discontinuous deposits (lenses) of sand and gravel at scattered elevations. Braided streams and sub-ice channels formed sinuous sand and gravel deposits, which are not continuous over broad areas. Further disruption of deposits resulted from glacial scour and shoving. Discontinuous aquifers supply adequate water for domestic needs; however, the larger yields necessary for agricultural, industrial and municipal needs may be unavailable. Most wells penetrate several lenses of sand and gravel.

One area of discontinuous sand and gravel, located between the Tippecanoe and Eel Rivers in Kosciusko, Wabash, and Whitley Counties (fig. 41), extends northeast into the St. Joseph River basin. This area is within the Steuben Morainal Lake physiographic area and is mapped as morainal topography by Gray (1989). The area is labeled "moraine complex" on hydrogeologic sections 5F–5F′ (fig. 40) and as "Mississinewa Moraine" in Tps. 31 and 32 N. in hydrogeologic section 5G–5G′ (fig. 40).

The second area of discontinuous sand and gravel is in eastern Clinton and western Howard Counties, within the Tipton Till Plain (fig. 41). This area does not coincide with mapped surficial geologic features (Gray, 1989), although thick morainal deposits are present in the subsurface. The lack of aquifer continuity in this buried moraine area is shown in Tps. 22 and 23 N.of hydrogeologic section 5C–5C′ (fig. 40). Parts of another discontinuous aquifer deposit are present in Jasper, Pulaski, and Starke Counties (fig. 41). Most of this discontinuous aquifer area is outside this basin and within the Kankakee River basin.

In areas with discontinuous sand and gravel aquifers, the interconnection between ground water and surface water is not evident due to the low permeability of the enclosing materials. Water in discontinuous sand and gravel aquifers is generally confined. When several discontinuous aquifers are penetrated, the potentiometric head in each successive aquifer is generally lower than the potentiometric head of the aquifer above it. This is indicative of ground-water recharge through low-permeability materials. Well yields (exclusive of domestic wells) from discontinuous sand and gravel deposits range from 20 to 300 gal/min, with a median of 90 gal/min (Nyman and Pettijohn, 1971, p. 47). Median depth of wells in discontinuous sand and gravel aquifers is slightly greater than that of wells in continuous sand and gravel (buried and surficial) to accommodate larger drawdowns.

Sand and Gravel Within Buried Preglacial Bedrock Valleys

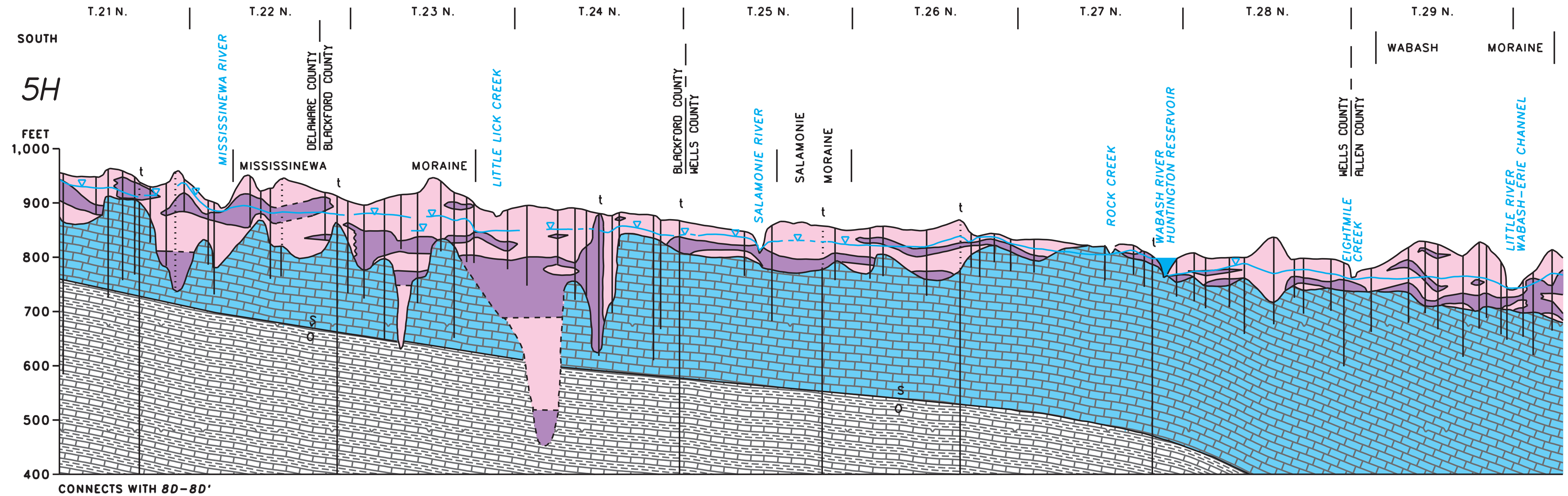
During this century, information obtained by exploratory drilling for oil and water has been used for delineation of a deeply buried preglacial valley system (fig. 7). The preglacial Lafayette Bedrock Valley (formerly known as the Teays Valley) crosses Indiana through the Upper Wabash River basin. Repeated glaciation filled the Lafayette Bedrock Valley with glacial and lake sediments. The valley was filled by different geologic events at different times. The Lafayette Bedrock Valley underlies 384 mi^2 (Nyman and Pettijohn, 1971, p. 55) of this basin.

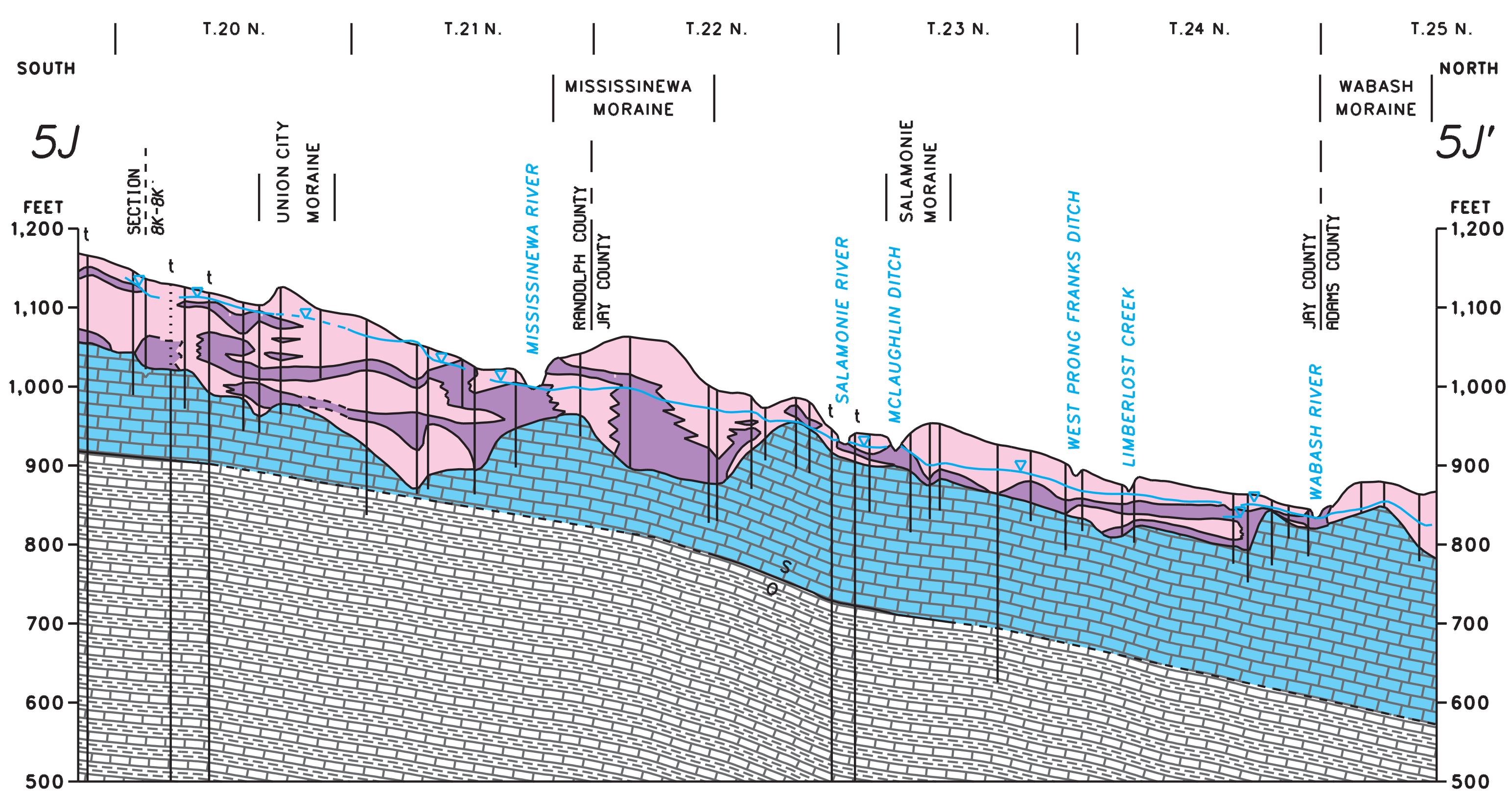
The only surface indications of the buried bedrock valley are in the area of Loblolly and Limberlost Creeks near Geneva in Adams and Jay Counties, and near Richvalley in Wabash and Miami Counties. Near Geneva, a swamp formed in the surface depression directly above the buried valley. This swamp is drained by Loblolly Creek, which follows the buried valley. The drape of the stratigraphy above this deep valley is shown in T. 24 N. of hydrogeologic section 5I–5I′ (fig. 40).

At Richvalley, the Wabash River's bedrock channel ends and the valley widens as the Lafayette Bedrock Valley tangentially crosses 170 ft below the river. Hydrogeologic section 5E–5E′ (fig. 40) transects the valley (T. 27 N.) between Richvalley and Peru. Although the Wabash River has a rock channel upstream and downstream, it has an alluvial channel in this area. Channel width and slump compaction of thick valley fill has facilitated the deposition of thin alluvial sediments over thick glacial outwash in the Richvalley area.

The stratigraphy of the valley fill has been recently studied. Bleuer (1991) and Bleuer and others (1991) report on the stratigraphy of unconsolidated deposits within the buried valley. Detailed stratigraphic information on the location of thick, highly transmissive unconsolidated deposits within the buried valley are intended to allow planners to locate high-yield wells. In summary, Bleuer and others (1991, p. 88) state the general rule "...west is best, east is least...," meaning that the buried aquifer has high yields from about Peru westward to Illinois, whereas productivity is less dependable eastward toward Ohio.

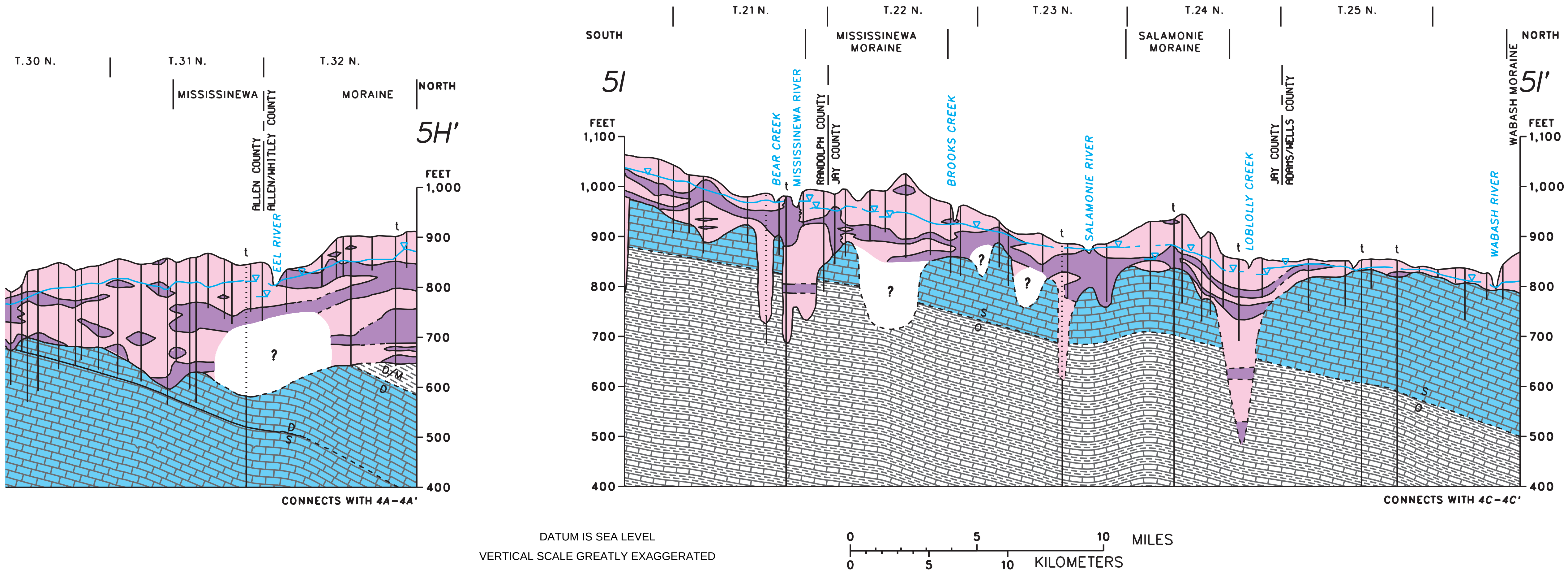
Figure 40. Hydrogeologic sections *5A–5A′* to *5J–5J′* of the Upper Wabash River basin—Continued.





The largest well yields in the Upper Wabash River basin are from unconsolidated aquifers in the buried bedrock valley. Yields from nondomestic wells ranged from 25 to 2,000 gal/min; a median yield of 700 gal/min is reported by Nyman and Pettijohn (1971, p. 47). The valley fill is very productive in several areas. Several municipal users withdraw ground water from aquifers in or just above the Lafayette Bedrock Valley. Cities in the Upper Wabash River basin that use the buried valley aquifer are Berne, Decatur, Geneva, Marion, La Fontaine, and Peru. Some valley fill aquifers are so thick and areally extensive that they can easily supply sustainable yields of tens of millions of gallons per day (Bleuer and others, 1991, p. 79).

Three areas of the Upper Wabash River basin are underlain by few unconsolidated aquifers. These three areas are (1) Adams and Wells County, (2) western Grant County, and (3) parts of White and Pulaski Counties. These three areas are similar in that thin drift deposits overlie scoured bedrock. Although yield from the drift-bedrock interface is small, a thin sand and gravel unit is generally present.



Bedrock Aquifers

Carbonate Bedrock Aquifers

A Silurian-Devonian carbonate bedrock aquifer underlies nearly all of the Upper Wabash River basin (fig. 41). Carbonate bedrock is absent from the base of the Lafayette Bedrock Valley in the eastern part of the basin, whereas it is 700 ft thick near the tricorner area of Allen, Whitley, and Noble Counties. Along the far northern side of the basin, increasing drift thickness and an overlying shale unit restrict access to the carbonate bedrock aquifer. The carbonate bedrock aquifer is not commonly used in areas where the overlying drift thickness exceeds 150 ft.

Ground-water flow in the carbonate bedrock aquifer is through vertical fractures, horizontal bedding planes, and solution openings. Karstification of the carbonate bedrock aquifer by surface water entering the ground-water system has further enhanced the secondary permeability of the carbonate bedrock aquifer throughout the basin. This secondary enhancement of permeability is responsible for the largest well yields available from the carbonate bedrock aquifer. Planert (1980, p. 15) found that the hydraulic conductivity of the carbonate bedrock aquifer in Allen County is greatest near the preglacial erosion surface and decreases with depth.

A ground-water divide separates regional ground-water flow in the northeastern part of the carbonate bedrock aquifer in the Upper Wabash River basin (Greeman, 1991). Northeast of this divide, more than 1,000 mi^2 of the Upper Wabash River basin, and part of the White River basin (fig. 1) drain toward the Maumee River basin. The ground-water flow in the regional carbonate bedrock aquifer is toward the Maumee River basin from as far west as Huntington, Ind. and as far south as Randolph County (fig. 36) (Greeman, 1991). Southwest of the regional ground-water flow divide in the Silurian-Devonian carbonate bedrock aquifer, ground-water flow is toward the Wabash River. Hydrogeologic sections 5G–5G′ to 5J–5J′ (fig. 40) illustrate these conclusions.

In the Upper Wabash River basin, yields from the Silurian-Devonian carbonate bedrock aquifer are suitable for domestic and stock uses. Yields suitable for small industries are common; however, large yields are less common. Well yields from the Silurian-Devonian carbonate bedrock aquifer system range from 15 to 1,250 gal/min. Median yields for nondomestic wells are 200 and 360 gal/min for the Silurian and Devonian carbonate rocks, respectively (Nyman and Pettijohn, 1971, p. 47).

The Silurian-Devonian carbonate bedrock aquifer system is the alternative ground-water source for the Upper Wabash River basin. If sufficient water is not found in the unconsolidated deposits, the carbonate bedrock is a dependable source in most of the area. North of the Eel and Tippecanoe Rivers, the carbonate bedrock aquifer is seldom used because water supply is available from shallower sand and gravel aquifers. South of the Eel and Tippecanoe Rivers, the carbonate bedrock aquifer is within 100 ft of the land surface in many areas; however, not all wells tap the carbonate rock, as domestic supplies are commonly available from sand and gravel deposits.

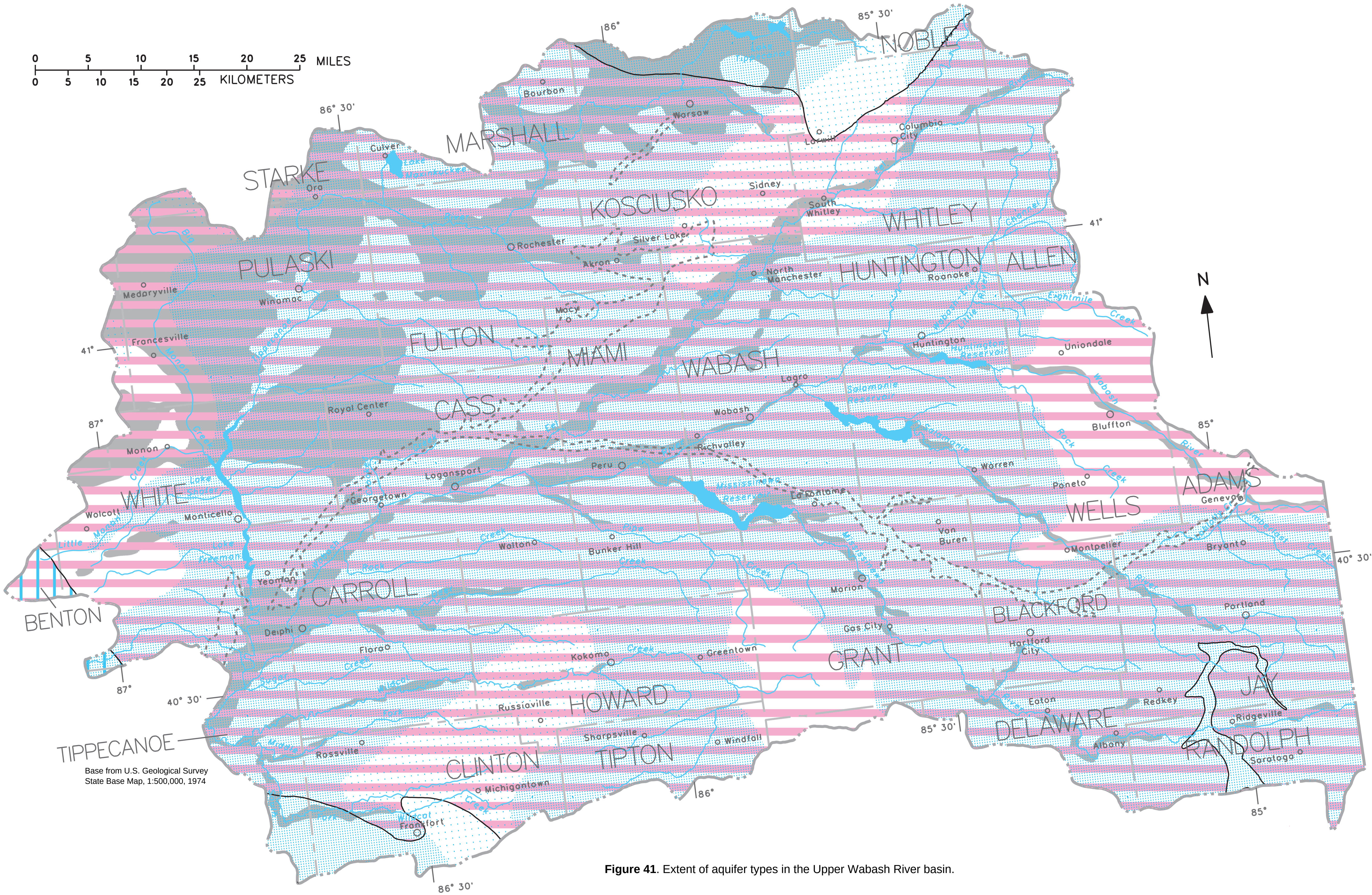


Figure 41. Extent of aquifer types in the Upper Wabash River basin.

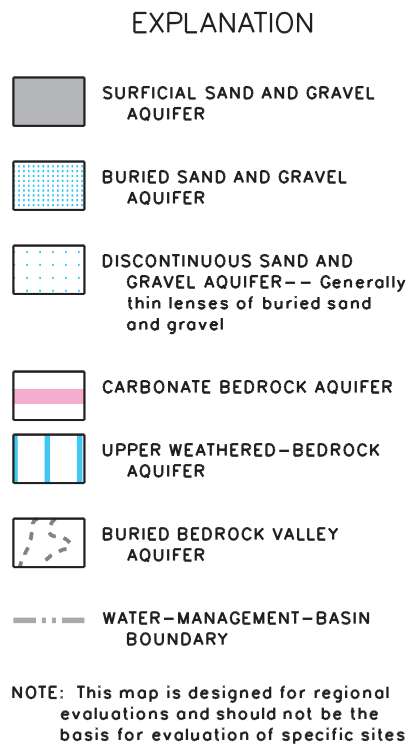


Table 7. Characteristics of aquifer types in the Upper Wabash River basin
[Locations of aquifer types shown in fig. 41]

Aquifer type	Thickness (feet)	Range of yield (gallons per minute)	Common name(s)
Surficial sand and gravel	0- 80	20- 1,350	
Buried sand and gravel	0-120	20- 1,000	
Discontinuous sand and gravel	0- 80	20- 300	
Sand and gravel in buried bedrock valley	0-200	25- 2,000	Lafayette Bedrock Valley aquifer[1]
Carbonate bedrock	0-700	15- 1,250	Silurian-Devonian carbonate bedrock aquifer
	0- 22	0- 200	Rockford Limestone

[1]Bleuer and others, 1991.

Where the carbonate rock is overlain by shale, ground-water circulation is restricted. This restriction allows time for accessory minerals to dissolve and degrade the quality of the ground water in the carbonate bedrock aquifer. Concentrations of dissolved minerals become objectionable in areas where circulation is restricted. A common objectionable constituent is sulfate, which dissolves from gypsum. Elevated concentrations of sulfate are primarily reported from carbonate rocks of Devonian age. Bleuer and Moore (1978, p. 43) report that ground water from the carbonate bedrock aquifer has significantly higher concentrations of dissolved strontium and sodium than ground water from the glaciofluvial aquifers.

A Lower Mississippian carbonate bedrock aquifer (Rockford Limestone) underlies the 100 mi^2 Borden Group subcrop in the far western part of the Upper Wabash River basin. Hydrogeologic section 5A–5A′ (fig. 40) indicates the location of the Rockford Limestone and its distribution. The Rockford Limestone is not a productive aquifer. It is, however, approximately 130 ft shallower than the Silurian-Devonian carbonate bedrock aquifer in this area. The Rockford Limestone attains a thickness of as much as 22 ft in this basin. Although well yields are small, they may be suitable for domestic needs.

The deep Ordovician and Cambrian rocks contain several potential aquifers. In the Upper Wabash River basin, however, these Ordovician and Cambrian rocks are not used as aquifers, because they are deeply buried and the water is saline.

Summary

The Upper Wabash River basin, located in north-central Indiana, is the largest water management basin (6,918 mi^2) in Indiana. It includes the cities of Bluffton, Columbia City, Frankfort, Hartford City, Huntington, Kokomo, Logansport, Marion, Monticello, North Manchester, Peru, Portland, Rochester, Wabash, and Warsaw.

Six different aquifer types were mapped within the basin (fig. 41): (1) surficial sand and gravel, (2) buried sand and gravel, (3) discontinuous buried sand and gravel, (4) sand and gravel within buried preglacial bedrock valleys, (5) carbonate bedrock of Silurian and Devonian ages and Lower Mississippian age, and (6) an upper weathered-bedrock aquifer in Mississippian shale.

The Upper Wabash River basin contains large volumes of usable ground water. The principal source of ground water in this basin is the unconsolidated deposits. More than 600 mi^2 of the basin is covered by surficial sand and gravel deposits, which average 30 ft in thickness (Nyman and Pettijohn, 1971, p. 55). Most surficial deposits are in the Tippecanoe River drainage. Domestic water supplies from buried sand and gravel aquifers are available throughout most of the basin. Yields from the sand and gravel aquifers range from 20 to 1,350 gal/min; the largest yields are in Kosciusko, Noble, and Whitley Counties.

The most productive aquifer system in the basin is within the buried Lafayette Bedrock Valley deposits. Some segments of the Lafayette Bedrock Valley contain unconsolidated deposits that are capable of producing as much as 2,000 gal/min. The cities of Decatur, Geneva, Marion, La Fontaine, and Peru derive all or part of their water supply from the buried-valley segments. Some valley-fill aquifers are so thick and areally extensive that they can supply sustainable yields of tens of millions of gallons per day.

The Silurian-Devonian carbonate bedrock aquifer is the primary bedrock ground-water resource. The carbonate bedrock aquifer is within 300 ft of the land surface in more than 80 percent of the Upper Wabash River basin. Yields of wells that tap carbonate bedrock aquifers in this basin range from 0 to 1,250 gal/min; however, the bedrock aquifer is seldom used in most areas because of the abundance of ground water in unconsolidated aquifers.

References Cited

Bassett, J.L., and Hasenmueller, N.R., 1979, Map showing structure on base of the New Albany Shale (Devonian and Mississippian) and equivalent strata in Indiana: Indiana Department of Natural Resources, Geological Survey, EGSP Series 800, scale 1:500,000.

Bassett, J.L., and Hasenmueller, N.R., 1980, Map of Indiana showing structure on top of the Maquoketa Group (Ordovician): Indiana Department of Natural Resources, Geological Survey, METC/EGSP Series 812, scale 1:500,000.

Bassett, P.A. and Keith, B.D., 1984, Data base for deep wells in Indiana: Indiana Department of Natural Resources, Geological Survey Occasional Paper 46, 29 p.

Bleuer, N.K., 1989, Historical and geomorphic concepts of the Lafayette Bedrock Valley system (so-called Teays valley) in Indiana: Indiana Department of Natural Resources, Geological Survey Special Report 46, 11 p.

_______1991, The Lafayette Bedrock Valley System of Indiana—concept, form, and fill stratigraphy, *in* Melhorn, W.N. and Kempton, J.P., eds., Geology and hydrogeology of the Teays-Mahomet Bedrock Valley System: Geological Society of America Special Paper 258, p. 51-77.

Bleuer, N.K., Melhorn, W.N., Steen, W.J. and Bruns, T.M., 1991, Aquifer systems of the buried Marion-Mahomet trunk valley (Lafayette Bedrock Valley System) of Indiana, *in* Melhorn, W.N. and Kempton, J.P., eds., Geology and Hydrogeology of the Teays-Mahomet Bedrock Valley System: Geological Society of America Special Paper 258, p. 79-89.

Bleuer, N.K., and Moore, M.C., 1972, Glacial stratigraphy of the Fort Wayne area and the draining of glacial Lake Maumee, *in* Proceedings of the Indiana Academy of Science for 1971: v. 81, p. 105-209.

_______1978, Environmental geology of Allen County, Indiana: Indiana Department of Natural Resources, Geological Survey Special Report 13, 72 p.

Bruns, T.M., Logan, S.M., and Steen, W.J., 1985a, Map showing bedrock topography of the Teays Valley, western part, north-central Indiana: Indiana Department of Natural Resources, Geological Survey Miscellaneous Map 42, scale 1:100,000.

_____1985b, Map showing bedrock topography of the Teays Valley, central part, north-central Indiana: Indiana Department Natural Resources, Geological Survey Miscellaneous Map 43, scale 1:100,000.

_____1985c, Map showing bedrock topography of the Teays Valley, eastern part, north-central Indiana: Indiana Department Natural Resources, Geological Survey Miscellaneous Map 44, scale 1:100,000.

Capps, S.R., 1910, The underground waters of north-central Indiana: U.S. Geological Survey Water-Supply Paper 254, 279 p.

Cazee, Sherry, 1988, Catalog of core samples of the Indiana Geological Survey: Indiana Department of Natural Resources, Geological Survey Directory 9, 83 p.

Chamberlin, T.C., 1883, Preliminary paper on the terminal moraine of the second glacial epoch: U.S. Geological Survey, Third Annual Report, 1881-1882, p. 291-402.

Clark, G.D., ed., 1980, The Indiana water resource—availability, uses, and needs: Indianapolis, Governor's Water Resources Study Commission, Indiana Department of Natural Resources, 508 p.

Droste, J.D., and Shaver, R.H., 1983, Atlas of early and middle Paleozoic paleogeography of the southern Great Lakes area: Indiana Department of Natural Resources, Geological Survey Special Report 32, 32 p.

Fullerton, D.S., 1980, Preliminary correlation of Post-Erie interstadial events (16,000-10,000 radiocarbon years before present), central and eastern Great Lakes region, and Hudson, Champlain, and St. Lawrence lowlands, United States and Canada: U.S. Geological Survey Professional Paper 1089, 52 p.

Gillies, D.G., 1981, Ground-water potential of the glacial deposits near Logansport, Cass County, Indiana: U.S. Geological Survey, Water-Resources Investigations 81-7, 98 p.

Gooding, A.M., 1973, Characteristics of Late Wisconsin tills in eastern Indiana: Indiana Department of Natural Resources, Geological Survey Bulletin 49, 28 p.

Gray, H.H., 1979, The Mississippian and Pennsylvanian (Carboniferous) systems in the United States—Indiana: U.S. Geological Survey Professional Paper 1110-K, 20 p.

_____1983, Map of Indiana showing thickness of unconsolidated deposits: Indiana Department of Natural Resources, Geological Survey Miscellaneous Map 37, scale 1:500,000.

_____1989, Quaternary geologic map of Indiana: Indiana Department of Natural Resources, Geological Survey Miscellaneous Map 49, scale 1:500,000.

Gray, H.H., Ault, C.H., and Keller, S.J., 1987, Bedrock geologic map of Indiana: Indiana Department of Natural Resources, Geological Survey Miscellaneous Map 48, scale 1:500,000.

Greeman, T.K., 1991, Areal differences between ground-water and surface-water drainage basins in Indiana [abs.]: Midwest Ground Water Conference, 36th, Indianapolis, 1991, program with abstracts, p. 106-107.

Harrell, Marshall, 1935, Ground water in Indiana: Indiana Department of Public Works, Conservation Department, Division of Geology Publication 133, 504 p.

Harrison, Wyman, 1958, Marginal zones of vanished glaciers reconstructed from the preconsolidation-pressure values of overridden silts: Journal of Geology, v. 66, n. 1, January 1958, p. 72-95.

Hasenmueller, N.R. and Bassett, J.L., 1980a, Map of Indiana showing thickness of New Albany Shale (Devonian and Mississippian) and equivalent strata: Indiana Department of Natural Resources, Geological Survey, EGSP Series 805, scale 1:500,000.

_____1980b, Map of Indiana showing structure on top of Silurian rocks: Indiana Department of Natural Resources, Geological Survey, METC/EGSP Series 811, scale 1:500,000.

_____1980c, Map of Indiana showing structure on top of the Trenton Limestone (Ordovician): Indiana Department of Natural Resources, Geological Survey, METC/EGSP Series 813.

Hoggatt, R.E., 1975, Drainage areas of Indiana streams: U.S. Geological Survey, 231 p.

Hoggatt, R.E., Hunn, J.K., and Steen, W.J., 1968, Water resources of Delaware County, Indiana: Indiana Department of Natural Resources, Division of Water Bulletin 37, 57 p.

Indiana, State of, 1989, Nonpoint source assessment report, part II: Indiana Department of Environmental Management, 28 p.

Marie, J.R. and Davis, L.G., 1974, Water resources of the middle Wabash River basin, Indiana: U.S. Geological Survey Hydrologic Investigations Atlas HA-508, 3 sheets.

McBeth, W.A., 1902, Wabash River terraces in Tippecanoe County, Indiana, *in* Proceedings of the Indiana Academy of Science for 1901: Indianapolis, Ind., p. 237-243.

Nyman, D.J., and Pettijohn, R.A., 1971, Ground water, *in* Wabash River Coordinating Committee, Wabash River basin comprehensive study: U.S. Army Corps of Engineers, Louisville Ky., volume VIII, appendix G, 100 p.

Palmer, A.R., 1983, Decade of North American geology—1983 geologic time scale: Geology, v. 11, p. 503-504.

Planert, Michael, 1980, Ground-water availability near Fort Wayne, Allen County, Indiana: U.S. Geological Survey Water-Resources Investigations 80-34, 54 p.

Rosenshein, J.S., 1958, Ground-water resources of Tippecanoe County, Indiana: Indiana Department of Conservation, Division of Water Resources Bulletin 8, 37 p.

Rosenshein, J.S. and Cosner, O.J., 1956, Ground-water resources of Tippecanoe County, Indiana—appendix, basic data: Indiana Department of Conservation, Division of Water Resources Bulletin 8, 65 p.

Rosenshein, J.S. and Hunn, J.D., 1964a, Ground-water resources of northwestern Indiana—preliminary report, Marshall County: Indiana Department of Conservation, Division of Water Resources Bulletin 19, 157 p.

_____1964b, Ground-water resources of northwestern Indiana—preliminary report, Fulton County: Indiana Department of Conservation, Division of Water Resources Bulletin 20, 83 p.

_____1964c, Ground-water resources of northwestern Indiana—preliminary report, Starke County: Indiana Department of Conservation, Division of Water Resources Bulletin 22, 87 p.

_____1964d, Ground-water resources of northwestern Indiana—preliminary report, Pulaski County: Indiana Department of Conservation, Division of Water Resources Bulletin 24, 71 p.

Schneider, A.F., 1966, Physiography, *in* Lindsey, A.A., ed, Natural features of Indiana: Indianapolis, Indiana Academy of Science, p. 40-56.

Shaver, R.H.; Ault, C.H.; Burger, A.M.; Carr, D.D.; Droste, J.B.; Eggert, D.L.; Gray, H.H.; Harper, Denver; Hasenmueller, N.R.; Hasenmueller, W.A.; Horowitz, A.S.; Hutchison, H.C.; Keith, B.D.; Keller, S.J.; Patton, J.B.; Rexroad, C.B.; and Wier, C.E.; 1986, Compendium of Paleozoic rock-unit stratigraphy in Indiana—a revision: Indiana Department of Natural Resources, Geological Survey Bulletin 59, 203 p.

Shaver, R.H.; Burger, A.M.; Gates, G.R.; Gray, H.H.; Hutchison, H.C.; Keller, S.J.; Patton, J.B.; Rexroad, C.B.; Smith, N.M.; Wayne, W. J.; and Wier, C.E., 1970, Compendium of rock-unit stratigraphy in Indiana: Indiana Department of Natural Resources, Geological Survey Bulletin 43, 229 p.

Smith, B.S., Hardy, M.A., and Crompton, E.J., 1985, Water resources of Wildcat Creek and Deer Creek basins, Howard and parts of adjacent Counties, Indiana, 1979-82: U.S. Geological Survey Water-Resources Investigations Report 85-4076, 92 p.

Stallmam, R.W. and Klaer, F.H., Jr., 1950, Ground-water resources of Noble County, Indiana: Indiana Department of Conservation, Division of Water Resources Bulletin 5, 103 p.

Tate, C.H.; Davis, L.G.; Johnson, L.E.; and Pettijohn, R.A., 1973, Water resources of the Upper Wabash River Basin, northeastern Indiana: U.S. Geological Survey Hydrologic Investigations Atlas HA-433, 3 sheets.

Wabash River Coordinating Committee, 1971, Wabash River Basin comprehensive study: Louisville, Ky., U.S. Army Corps of Engineers, 14 v., variable pagination.

Watkins, F.A., Jr., and Rosenshein, J.S., 1963, Ground-water geology and hydrology of Bunker Hill Air Force Base and vicinity, Peru, Indiana: U.S. Geological Survey Water-Supply Paper 1619-B, 32 p.

Watkins, F.A., Jr., and Ward, P.E., 1962, Ground-water resources of Adams County, Indiana: Indiana Department of Conservation, Division of Water Resources Bulletin 9, 67 p.

Wayne, W.J., 1963, Pleistocene formations of Indiana: Indiana Department of Conservation, Geological Survey Bulletin 25, 85 p.